



Cambridge International AS & A Level

CANDIDATE
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CHEMISTRY

9701/34

Paper 3 Advanced Practical Skills 2

May/June 2020

2 hours

You must answer on the question paper.

You will need: The materials and apparatus listed in the confidential instructions

INSTRUCTIONS

- Answer **all** questions.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working, use appropriate units and use an appropriate number of significant figures.
- Give details of the practical session and laboratory, where appropriate, in the boxes provided.

| |
|-------------------|
| Session |
| |
| Laboratory |
| |

INFORMATION

- The total mark for this paper is 40.
- The number of marks for each question or part question is shown in brackets [].
- The Periodic Table is printed in the question paper.
- Notes for use in qualitative analysis are provided in the question paper.

| For Examiner's Use | |
|---------------------------|--|
| 1 | |
| 2 | |
| 3 | |
| Total | |

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This document has **12** pages. Blank pages are indicated.

Quantitative Analysis

Read through the whole method before starting any practical work. Where appropriate, prepare a table for your results in the space provided.

Show your working and appropriate significant figures in the final answer to **each** step of your calculations.

- 1 **FB 1** is a solution of hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$, where x is an integer. You will determine the value of x in this compound by a titration method.

You will add **FB 1** to a known volume and concentration of hydrochloric acid, **FB 2**. The hydrochloric acid is in excess. You will then titrate the remaining acid with aqueous sodium hydroxide, **FB 3**.

FB 1 is a solution containing 37.5 g dm^{-3} hydrated sodium carbonate, $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

FB 2 is $0.200 \text{ mol dm}^{-3}$ hydrochloric acid, HCl .

FB 3 is $0.100 \text{ mol dm}^{-3}$ sodium hydroxide, NaOH .
bromophenol blue indicator

(a) Method

- Fill the burette with **FB 3**.
- For each titration:
Use the **25 cm³** pipette to place 25.0 cm^3 of **FB 2** into a conical flask.
Use the **10 cm³** pipette to place 10.0 cm^3 of **FB 1** into the same conical flask.
- Add a few drops of bromophenol blue indicator.
- Titrate the contents of the conical flask with **FB 3** from the burette.
- Perform a rough titration and record your burette readings in the space below.

The rough titre is cm^3 .

- Carry out as many accurate titrations as you think necessary to obtain consistent results.
- Make sure any recorded results show the precision of your practical work.
- Record, in a suitable form below, all of your burette readings and the volume of **FB 3** added in each accurate titration.

| | |
|-----|--|
| I | |
| II | |
| III | |
| IV | |
| V | |
| VI | |
| VII | |

[7]

- (b) From your titration results, obtain a suitable value to be used in your calculations. Show clearly how you obtained this value.

volume of **FB 3** used in titration = cm³ [1]

(c) Calculations

- (i) Give your answers to (c)(ii), (c)(iii) and (c)(iv) to an appropriate number of significant figures. [1]
- (ii) Calculate the number of moles of sodium hydroxide present in the volume of **FB 3** calculated in (b).

moles of NaOH = mol

This number of moles of sodium hydroxide neutralises the remaining hydrochloric acid. Deduce the number of moles of remaining hydrochloric acid.

moles of remaining HCl = mol [1]

- (iii) Calculate the initial number of moles of hydrochloric acid in each 25.0 cm³ sample of **FB 2** pipetted into the conical flask.

initial moles of HCl in each sample of **FB 2** = mol

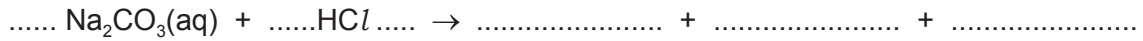
You have calculated

- the number of moles of remaining HCl
- the initial number of moles of HCl in each sample of **FB 2**.

Calculate the number of moles of hydrochloric acid neutralised by the Na₂CO₃·xH₂O in **FB 1** in each titration.

number of moles of HCl neutralised by the Na₂CO₃·xH₂O = mol [1]

(iv) Complete the equation. Include state symbols.



Deduce the number of moles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ present in each 10.0 cm^3 sample of **FB 1**.

number of moles of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ present = mol [1]

(v) **FB 1** contains 37.5 g dm^{-3} $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

Use your answer to (c)(iv) to calculate the relative formula mass, M_r , of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.
Show your working.

relative formula mass of $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$ = [2]

(vi) Determine the value of x in the formula $\text{Na}_2\text{CO}_3 \cdot x\text{H}_2\text{O}$.

$x = \text{.....}$ [1]

(d) A student suggested a different method.

- To 250 cm^3 of **FB 2**, add 100 cm^3 of **FB 1**.
- Pipette 25.0 cm^3 of this mixture of solutions into a conical flask.
- Titrate this mixture of solutions with **FB 3**.
- Repeat titrations until concordant results are achieved.

Comment on one disadvantage **or** one advantage of using this method rather than the method you used in (a).

.....

 [1]

[Total: 16]

- 2 You will now investigate a different hydrated salt with the formula $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$, where **M** is a Group 2 metal. By heating a sample of $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$ to produce anhydrous MSO_4 you will determine its relative formula mass and hence identify **M**.

FB 4 is the hydrated salt $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$.

(a) Method

- Weigh the crucible with its lid. Record the mass.
- Place between 1.80 g and 2.20 g of **FB 4** in the crucible.
- Reweigh the crucible, its lid and contents and record the mass.
- Without the lid, place the crucible on the pipe-clay triangle and heat gently for approximately 1 minute and then strongly for approximately 4 minutes.
- Place the lid on the crucible and leave it to cool.
- You may wish to start **Question 3** while you are waiting for the crucible to cool.
- Reweigh the crucible, its lid and contents and record the mass.
- Calculate, and record, the mass of **FB 4**, the mass of residue after heating and the mass of water lost.

[4]

(b) Calculations

- (i) Calculate the number of moles of water lost when your sample of $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$ was heated.

moles of water = mol [1]

- (ii) Write the equation for the reaction that occurs when $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$ is heated. Include state symbols.

.....

Deduce the number of moles of anhydrous salt, MSO_4 , left after the heating.

moles of MSO_4 = mol
[1]

- (iii) Calculate the relative formula mass, M_r , of $\text{MSO}_4 \cdot 7\text{H}_2\text{O}$.

$$M_r \text{ of } \text{MSO}_4 \cdot 7\text{H}_2\text{O} = \dots\dots\dots [1]$$

- (iv) Determine the relative atomic mass, A_r , of **M** and hence identify **M**.
Show your working.

$$A_r = \dots\dots\dots$$

$$\mathbf{M} \text{ is } \dots\dots\dots [2]$$

- (c) (i) In the method used above, the lid was placed on the crucible when the crucible was left to cool.

Explain why the lid was placed on the crucible.

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

- (ii) Suggest and explain the effect on the calculated value of the relative atomic mass of **M** if the lid had not been placed on the crucible during cooling.

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

[Total: 11]

Qualitative Analysis

Where reagents are selected for use in a test, the **name** or **correct formula** of the element or compound must be given.

At each stage of any test you are to record details of the following:

- colour changes seen
- the formation of any precipitate and its solubility in an excess of the reagent added
- the formation of any gas and its identification by a suitable test.

You should indicate clearly at what stage in a test a change occurs.

If any solution is warmed, a **boiling tube** must be used.

Rinse and reuse test-tubes and boiling tubes where possible.

No additional tests for ions present should be attempted.

- 3 In this question you may need Tollens' reagent. To prepare this, place a 2–3 cm depth of aqueous silver nitrate in a test-tube, add aqueous sodium hydroxide drop by drop until a small amount of brown precipitate is formed and then add aqueous ammonia drop by drop with shaking until the precipitate just dissolves. This is Tollens' reagent. If Tollens' reagent is used, ensure that all test-tubes are thoroughly rinsed immediately after use.

Half fill the 250 cm³ beaker with water and heat to boiling. Then turn off the Bunsen burner. This will be used as a hot water bath.

- (a) (i) You are to investigate some reactions of solid **FB 5**.

To a 2 cm depth of aqueous ammonium vanadate(V) in a test-tube add a small spatula measure of **FB 5**. Leave for approximately 4 minutes with occasional shaking.

Record all the changes that you observe.

Keep the test-tube and its contents for use in the next test.

.....

.....

.....

..... [2]

- (ii) Transfer a 1 cm depth of the **solution** from (a)(i) into a test-tube and add acidified potassium manganate(VII) a few drops at a time until no further reaction occurs. At this stage the solution is pink because unreacted KMnO_4 is present.

Record all the changes that you observe.

.....

 [1]

- (iii) State the type of reaction occurring in the test in (a)(ii).

..... [1]

- (iv) To a 1 cm depth of dilute sulfuric acid in a test-tube add a small spatula measure of **FB 5**. Record your observations. Place the test-tube in the hot water bath if necessary to start the reaction.

.....
 [2]

- (b) **FB 6** is an aqueous solution that has been made by reacting solid **FB 5** with dilute sulfuric acid.

- (i) Carry out the following tests and record your observations.

| <i>test</i> | <i>observations</i> |
|----------------------------------------------------------------------------------------------|---------------------|
| Test 1 To a 1 cm depth of FB 6 in a test-tube add aqueous sodium hydroxide. | |
| Test 2 To a 1 cm depth of FB 6 in a test-tube add aqueous ammonia. | |

[2]

- (ii) Identify **FB 5**.

FB 5 is [1]

- (iii) Give the equation for the reaction of **FB 5** with sulfuric acid to make **FB 6**. Include state symbols.

..... [1]

(c) **FB 7** is either ethanal, CH_3CHO , or propanone, CH_3COCH_3 .

- (i) Describe a test that would enable you to identify which of these compounds is present in **FB 7**. You should state the observation expected for ethanal and propanone.

test

.....

expected observations

ethanal

propanone

[2]

- (ii) Carry out this test on **FB 7**. Record the result of the test and hence identify **FB 7**.

result

FB 7 is

[1]

[Total: 13]

Qualitative Analysis Notes

1 Reactions of aqueous cations

| ion | reaction with | |
|------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| | NaOH(aq) | NH ₃ (aq) |
| aluminium, Al ³⁺ (aq) | white ppt. soluble in excess | white ppt. insoluble in excess |
| ammonium, NH ₄ ⁺ (aq) | no ppt. ammonia produced on heating | – |
| barium, Ba ²⁺ (aq) | faint white ppt. is nearly always observed unless reagents are pure | no ppt. |
| calcium, Ca ²⁺ (aq) | white ppt. with high [Ca ²⁺ (aq)] | no ppt. |
| chromium(III), Cr ³⁺ (aq) | grey-green ppt. soluble in excess | grey-green ppt. insoluble in excess |
| copper(II), Cu ²⁺ (aq) | pale blue ppt. insoluble in excess | blue ppt. soluble in excess giving dark blue solution |
| iron(II), Fe ²⁺ (aq) | green ppt. turning brown on contact with air insoluble in excess | green ppt. turning brown on contact with air insoluble in excess |
| iron(III), Fe ³⁺ (aq) | red-brown ppt. insoluble in excess | red-brown ppt. insoluble in excess |
| magnesium, Mg ²⁺ (aq) | white ppt. insoluble in excess | white ppt. insoluble in excess |
| manganese(II), Mn ²⁺ (aq) | off-white ppt. rapidly turning brown on contact with air insoluble in excess | off-white ppt. rapidly turning brown on contact with air insoluble in excess |
| zinc, Zn ²⁺ (aq) | white ppt. soluble in excess | white ppt. soluble in excess |

2 Reactions of anions

| <i>ion</i> | <i>reaction</i> |
|-------------------------------------------|-------------------------------------------------------------------------------------------------|
| carbonate, CO_3^{2-} | CO_2 liberated by dilute acids |
| chloride, $\text{Cl}^-(\text{aq})$ | gives white ppt. with $\text{Ag}^+(\text{aq})$ (soluble in $\text{NH}_3(\text{aq})$) |
| bromide, $\text{Br}^-(\text{aq})$ | gives cream ppt. with $\text{Ag}^+(\text{aq})$ (partially soluble in $\text{NH}_3(\text{aq})$) |
| iodide, $\text{I}^-(\text{aq})$ | gives yellow ppt. with $\text{Ag}^+(\text{aq})$ (insoluble in $\text{NH}_3(\text{aq})$) |
| nitrate, $\text{NO}_3^-(\text{aq})$ | NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil |
| nitrite, $\text{NO}_2^-(\text{aq})$ | NH_3 liberated on heating with $\text{OH}^-(\text{aq})$ and Al foil |
| sulfate, $\text{SO}_4^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (insoluble in excess dilute strong acids) |
| sulfite, $\text{SO}_3^{2-}(\text{aq})$ | gives white ppt. with $\text{Ba}^{2+}(\text{aq})$ (soluble in excess dilute strong acids) |

3 Tests for gases

| <i>gas</i> | <i>test and test result</i> |
|-------------------------------|-------------------------------------------------------------------------------|
| ammonia, NH_3 | turns damp red litmus paper blue |
| carbon dioxide, CO_2 | gives a white ppt. with limewater (ppt. dissolves with excess CO_2) |
| chlorine, Cl_2 | bleaches damp litmus paper |
| hydrogen, H_2 | 'pops' with a lighted splint |
| oxygen, O_2 | relights a glowing splint |

The Periodic Table of Elements

| | | Group | | | | | | | | | | | | | | | |
|---|---|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">1 H hydrogen 1.0</div> <div style="border: 1px solid black; padding: 2px;">2 He helium 4.0</div> </div> | | | | | | | | | | | | | | | |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">3 Li lithium 6.9</div> <div style="border: 1px solid black; padding: 2px;">4 Be beryllium 9.0</div> <div style="border: 1px solid black; padding: 2px;">5 B boron 10.8</div> <div style="border: 1px solid black; padding: 2px;">6 C carbon 12.0</div> <div style="border: 1px solid black; padding: 2px;">7 N nitrogen 14.0</div> <div style="border: 1px solid black; padding: 2px;">8 O oxygen 16.0</div> <div style="border: 1px solid black; padding: 2px;">9 F fluorine 19.0</div> <div style="border: 1px solid black; padding: 2px;">10 Ne neon 20.2</div> </div> | | | | | | | | | | | | | | | |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">11 Na sodium 23.0</div> <div style="border: 1px solid black; padding: 2px;">12 Mg magnesium 24.3</div> <div style="border: 1px solid black; padding: 2px;">13 Al aluminium 27.0</div> <div style="border: 1px solid black; padding: 2px;">14 Si silicon 28.1</div> <div style="border: 1px solid black; padding: 2px;">15 P phosphorus 31.0</div> <div style="border: 1px solid black; padding: 2px;">16 S sulfur 32.1</div> <div style="border: 1px solid black; padding: 2px;">17 Cl chlorine 35.5</div> <div style="border: 1px solid black; padding: 2px;">18 Ar argon 39.9</div> </div> | | | | | | | | | | | | | | | |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">19 K potassium 39.1</div> <div style="border: 1px solid black; padding: 2px;">20 Ca calcium 40.1</div> <div style="border: 1px solid black; padding: 2px;">21 Sc scandium 45.0</div> <div style="border: 1px solid black; padding: 2px;">22 Ti titanium 47.9</div> <div style="border: 1px solid black; padding: 2px;">23 V vanadium 50.9</div> <div style="border: 1px solid black; padding: 2px;">24 Cr chromium 52.0</div> <div style="border: 1px solid black; padding: 2px;">25 Mn manganese 54.9</div> <div style="border: 1px solid black; padding: 2px;">26 Fe iron 55.8</div> <div style="border: 1px solid black; padding: 2px;">27 Co cobalt 58.9</div> <div style="border: 1px solid black; padding: 2px;">28 Ni nickel 58.7</div> <div style="border: 1px solid black; padding: 2px;">29 Cu copper 63.5</div> <div style="border: 1px solid black; padding: 2px;">30 Zn zinc 65.4</div> <div style="border: 1px solid black; padding: 2px;">31 Ga gallium 69.7</div> <div style="border: 1px solid black; padding: 2px;">32 Ge germanium 72.6</div> <div style="border: 1px solid black; padding: 2px;">33 As arsenic 74.9</div> <div style="border: 1px solid black; padding: 2px;">34 Se selenium 79.0</div> <div style="border: 1px solid black; padding: 2px;">35 Br bromine 79.9</div> <div style="border: 1px solid black; padding: 2px;">36 Kr krypton 83.8</div> </div> | | | | | | | | | | | | | | | |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">37 Rb rubidium 85.5</div> <div style="border: 1px solid black; padding: 2px;">38 Sr strontium 87.6</div> <div style="border: 1px solid black; padding: 2px;">39 Y yttrium 88.9</div> <div style="border: 1px solid black; padding: 2px;">40 Zr zirconium 91.2</div> <div style="border: 1px solid black; padding: 2px;">41 Nb niobium 92.9</div> <div style="border: 1px solid black; padding: 2px;">42 Mo molybdenum 95.9</div> <div style="border: 1px solid black; padding: 2px;">43 Tc technetium —</div> <div style="border: 1px solid black; padding: 2px;">44 Ru ruthenium 101.1</div> <div style="border: 1px solid black; padding: 2px;">45 Rh rhodium 102.9</div> <div style="border: 1px solid black; padding: 2px;">46 Pd palladium 106.4</div> <div style="border: 1px solid black; padding: 2px;">47 Ag silver 107.9</div> <div style="border: 1px solid black; padding: 2px;">48 Cd cadmium 112.4</div> <div style="border: 1px solid black; padding: 2px;">49 In indium 114.8</div> <div style="border: 1px solid black; padding: 2px;">50 Sn tin 118.7</div> <div style="border: 1px solid black; padding: 2px;">51 Sb antimony 121.8</div> <div style="border: 1px solid black; padding: 2px;">52 Te tellurium 127.6</div> <div style="border: 1px solid black; padding: 2px;">53 I iodine 126.9</div> <div style="border: 1px solid black; padding: 2px;">54 Xe xenon 131.3</div> </div> | | | | | | | | | | | | | | | |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">55 Cs caesium 132.9</div> <div style="border: 1px solid black; padding: 2px;">56 Ba barium 137.3</div> <div style="border: 1px solid black; padding: 2px;">57–71 lanthanoids —</div> <div style="border: 1px solid black; padding: 2px;">72 Hf hafnium 178.5</div> <div style="border: 1px solid black; padding: 2px;">73 Ta tantalum 180.9</div> <div style="border: 1px solid black; padding: 2px;">74 W tungsten 183.8</div> <div style="border: 1px solid black; padding: 2px;">75 Re rhenium 186.2</div> <div style="border: 1px solid black; padding: 2px;">76 Os osmium 190.2</div> <div style="border: 1px solid black; padding: 2px;">77 Ir iridium 192.2</div> <div style="border: 1px solid black; padding: 2px;">78 Pt platinum 195.1</div> <div style="border: 1px solid black; padding: 2px;">79 Au gold 197.0</div> <div style="border: 1px solid black; padding: 2px;">80 Hg mercury 200.6</div> <div style="border: 1px solid black; padding: 2px;">81 Tl thallium 204.4</div> <div style="border: 1px solid black; padding: 2px;">82 Pb lead 207.2</div> <div style="border: 1px solid black; padding: 2px;">83 Bi bismuth 209.0</div> <div style="border: 1px solid black; padding: 2px;">84 Po polonium —</div> <div style="border: 1px solid black; padding: 2px;">85 At astatine —</div> <div style="border: 1px solid black; padding: 2px;">86 Rn radon —</div> </div> | | | | | | | | | | | | | | | |
| | | <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="border: 1px solid black; padding: 2px;">87 Fr francium —</div> <div style="border: 1px solid black; padding: 2px;">88 Ra radium —</div> <div style="border: 1px solid black; padding: 2px;">89–103 actinoids —</div> <div style="border: 1px solid black; padding: 2px;">104 Rf rutherfordium —</div> <div style="border: 1px solid black; padding: 2px;">105 Db dubnium —</div> <div style="border: 1px solid black; padding: 2px;">106 Sg seaborgium —</div> <div style="border: 1px solid black; padding: 2px;">107 Bh bohrium —</div> <div style="border: 1px solid black; padding: 2px;">108 Hs hassium —</div> <div style="border: 1px solid black; padding: 2px;">109 Mt meitnerium —</div> <div style="border: 1px solid black; padding: 2px;">110 Ds darmstadtium —</div> <div style="border: 1px solid black; padding: 2px;">111 Rg roentgenium —</div> <div style="border: 1px solid black; padding: 2px;">112 Cn copernicium —</div> <div style="border: 1px solid black; padding: 2px;">114 Fl flerovium —</div> <div style="border: 1px solid black; padding: 2px;">116 Lv livermorium —</div> </div> | | | | | | | | | | | | | | | |

lanthanoids

| | | | | | | | | | | | | | | |
|--------------------------------|------------------------------|-----------------------------------|--------------------------------|-----------------------------|-------------------------------|-------------------------------|---------------------------------|------------------------------|---------------------------------|------------------------------|-----------------------------|-------------------------------|--------------------------------|-------------------------------|
| 57 La lanthanum 138.9 | 58 Ce cerium 140.1 | 59 Pr praseodymium 140.9 | 60 Nd neodymium 144.4 | 61 Pm promethium — | 62 Sm samarium 150.4 | 63 Eu europium 152.0 | 64 Gd gadolinium 157.3 | 65 Tb terbium 158.9 | 66 Dy dysprosium 162.5 | 67 Ho holmium 164.9 | 68 Er erbium 167.3 | 69 Tm thulium 168.9 | 70 Yb ytterbium 173.1 | 71 Lu lutetium 175.0 |
| 89 Ac actinium — | 90 Th thorium 232.0 | 91 Pa protactinium 231.0 | 92 U uranium 238.0 | 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 — |

actinoids