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**Technetium**

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| --- | --- |
| Technetium,  43Tc | |
| [Technetium.jpg](https://en.wikipedia.org/wiki/File:Technetium.jpg) | |
| **General properties** | |
| **Pronunciation** | [/tɛkˈniːʃiəm/](https://en.wikipedia.org/wiki/Help:IPA/English) ​([*tek-NEE-shee-əm*](https://en.wikipedia.org/wiki/Help:Pronunciation_respelling_key)) |
| **Appearance** | shiny gray metal |
| [**Mass number**](https://en.wikipedia.org/wiki/Mass_number) | 98 (most stable isotope) |
| **Technetium in the** [**periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 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[Neon](https://en.wikipedia.org/wiki/Neon) | | [Sodium](https://en.wikipedia.org/wiki/Sodium) | [Magnesium](https://en.wikipedia.org/wiki/Magnesium) |  | | | | | | | | | | | | | | | | | | | | | | | | [Aluminium](https://en.wikipedia.org/wiki/Aluminium) | [Silicon](https://en.wikipedia.org/wiki/Silicon) | [Phosphorus](https://en.wikipedia.org/wiki/Phosphorus) | [Sulfur](https://en.wikipedia.org/wiki/Sulfur) | [Chlorine](https://en.wikipedia.org/wiki/Chlorine) | [Argon](https://en.wikipedia.org/wiki/Argon) | | [Potassium](https://en.wikipedia.org/wiki/Potassium) | [Calcium](https://en.wikipedia.org/wiki/Calcium) | [Scandium](https://en.wikipedia.org/wiki/Scandium) |  | | | | | | | | | | | | | | [Titanium](https://en.wikipedia.org/wiki/Titanium) | [Vanadium](https://en.wikipedia.org/wiki/Vanadium) | [Chromium](https://en.wikipedia.org/wiki/Chromium) | [Manganese](https://en.wikipedia.org/wiki/Manganese) | [Iron](https://en.wikipedia.org/wiki/Iron) | [Cobalt](https://en.wikipedia.org/wiki/Cobalt) | [Nickel](https://en.wikipedia.org/wiki/Nickel) | [Copper](https://en.wikipedia.org/wiki/Copper) | [Zinc](https://en.wikipedia.org/wiki/Zinc) | [Gallium](https://en.wikipedia.org/wiki/Gallium) | [Germanium](https://en.wikipedia.org/wiki/Germanium) | [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | [Selenium](https://en.wikipedia.org/wiki/Selenium) | [Bromine](https://en.wikipedia.org/wiki/Bromine) | [Krypton](https://en.wikipedia.org/wiki/Krypton) | | [Rubidium](https://en.wikipedia.org/wiki/Rubidium) | [Strontium](https://en.wikipedia.org/wiki/Strontium) | [Yttrium](https://en.wikipedia.org/wiki/Yttrium) |  |  | | | | | | | | | | | | | [Zirconium](https://en.wikipedia.org/wiki/Zirconium) | [Niobium](https://en.wikipedia.org/wiki/Niobium) | [Molybdenum](https://en.wikipedia.org/wiki/Molybdenum) | Technetium | [Ruthenium](https://en.wikipedia.org/wiki/Ruthenium) | [Rhodium](https://en.wikipedia.org/wiki/Rhodium) | [Palladium](https://en.wikipedia.org/wiki/Palladium) | [Silver](https://en.wikipedia.org/wiki/Silver) | [Cadmium](https://en.wikipedia.org/wiki/Cadmium) | [Indium](https://en.wikipedia.org/wiki/Indium) | [Tin](https://en.wikipedia.org/wiki/Tin) | [Antimony](https://en.wikipedia.org/wiki/Antimony) | [Tellurium](https://en.wikipedia.org/wiki/Tellurium) | [Iodine](https://en.wikipedia.org/wiki/Iodine) | [Xenon](https://en.wikipedia.org/wiki/Xenon) | | [Caesium](https://en.wikipedia.org/wiki/Caesium) | [Barium](https://en.wikipedia.org/wiki/Barium) | [Lanthanum](https://en.wikipedia.org/wiki/Lanthanum) | [Cerium](https://en.wikipedia.org/wiki/Cerium) | [Praseodymium](https://en.wikipedia.org/wiki/Praseodymium) | [Neodymium](https://en.wikipedia.org/wiki/Neodymium) | [Promethium](https://en.wikipedia.org/wiki/Promethium) | [Samarium](https://en.wikipedia.org/wiki/Samarium) | [Europium](https://en.wikipedia.org/wiki/Europium) | [Gadolinium](https://en.wikipedia.org/wiki/Gadolinium) | [Terbium](https://en.wikipedia.org/wiki/Terbium) | [Dysprosium](https://en.wikipedia.org/wiki/Dysprosium) | [Holmium](https://en.wikipedia.org/wiki/Holmium) | [Erbium](https://en.wikipedia.org/wiki/Erbium) | [Thulium](https://en.wikipedia.org/wiki/Thulium) | [Ytterbium](https://en.wikipedia.org/wiki/Ytterbium) | [Lutetium](https://en.wikipedia.org/wiki/Lutetium) | [Hafnium](https://en.wikipedia.org/wiki/Hafnium) | [Tantalum](https://en.wikipedia.org/wiki/Tantalum) | [Tungsten](https://en.wikipedia.org/wiki/Tungsten) | [Rhenium](https://en.wikipedia.org/wiki/Rhenium) | [Osmium](https://en.wikipedia.org/wiki/Osmium) | [Iridium](https://en.wikipedia.org/wiki/Iridium) | [Platinum](https://en.wikipedia.org/wiki/Platinum) | [Gold](https://en.wikipedia.org/wiki/Gold) | [Mercury (element)](https://en.wikipedia.org/wiki/Mercury_(element)) | [Thallium](https://en.wikipedia.org/wiki/Thallium) | [Lead](https://en.wikipedia.org/wiki/Lead) | [Bismuth](https://en.wikipedia.org/wiki/Bismuth) | [Polonium](https://en.wikipedia.org/wiki/Polonium) | [Astatine](https://en.wikipedia.org/wiki/Astatine) | [Radon](https://en.wikipedia.org/wiki/Radon) | | [Francium](https://en.wikipedia.org/wiki/Francium) | [Radium](https://en.wikipedia.org/wiki/Radium) | [Actinium](https://en.wikipedia.org/wiki/Actinium) | [Thorium](https://en.wikipedia.org/wiki/Thorium) | [Protactinium](https://en.wikipedia.org/wiki/Protactinium) | [Uranium](https://en.wikipedia.org/wiki/Uranium) | [Neptunium](https://en.wikipedia.org/wiki/Neptunium) | [Plutonium](https://en.wikipedia.org/wiki/Plutonium) | [Americium](https://en.wikipedia.org/wiki/Americium) | [Curium](https://en.wikipedia.org/wiki/Curium) | [Berkelium](https://en.wikipedia.org/wiki/Berkelium) | [Californium](https://en.wikipedia.org/wiki/Californium) | [Einsteinium](https://en.wikipedia.org/wiki/Einsteinium) | [Fermium](https://en.wikipedia.org/wiki/Fermium) | [Mendelevium](https://en.wikipedia.org/wiki/Mendelevium) | [Nobelium](https://en.wikipedia.org/wiki/Nobelium) | [Lawrencium](https://en.wikipedia.org/wiki/Lawrencium) | [Rutherfordium](https://en.wikipedia.org/wiki/Rutherfordium) | [Dubnium](https://en.wikipedia.org/wiki/Dubnium) | [Seaborgium](https://en.wikipedia.org/wiki/Seaborgium) | [Bohrium](https://en.wikipedia.org/wiki/Bohrium) | [Hassium](https://en.wikipedia.org/wiki/Hassium) | [Meitnerium](https://en.wikipedia.org/wiki/Meitnerium) | [Darmstadtium](https://en.wikipedia.org/wiki/Darmstadtium) | [Roentgenium](https://en.wikipedia.org/wiki/Roentgenium) | [Copernicium](https://en.wikipedia.org/wiki/Copernicium) | [Nihonium](https://en.wikipedia.org/wiki/Nihonium) | [Flerovium](https://en.wikipedia.org/wiki/Flerovium) | [Moscovium](https://en.wikipedia.org/wiki/Moscovium) | [Livermorium](https://en.wikipedia.org/wiki/Livermorium) | [Tennessine](https://en.wikipedia.org/wiki/Tennessine) | [Oganesson](https://en.wikipedia.org/wiki/Oganesson) | | [Mn](https://en.wikipedia.org/wiki/Manganese) ↑ **Tc** ↓ [Re](https://en.wikipedia.org/wiki/Rhenium) | | [molybdenum](https://en.wikipedia.org/wiki/Molybdenum) ← **technetium** → [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 43 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 7](https://en.wikipedia.org/wiki/Group_7_element) |
| [**Period**](https://en.wikipedia.org/wiki/Period_(periodic_table)) | [period 5](https://en.wikipedia.org/wiki/Period_(periodic_table)#Period_5) |
| [**Block**](https://en.wikipedia.org/wiki/Block_(periodic_table)) | [d-block](https://en.wikipedia.org/wiki/D-block) |
| [**Element category**](https://en.wikipedia.org/wiki/Names_for_sets_of_chemical_elements#Category) | [transition metal](https://en.wikipedia.org/wiki/Transition_metal) |
| [**Electron configuration**](https://en.wikipedia.org/wiki/Electron_configuration) | [[Kr](https://en.wikipedia.org/wiki/Krypton)] 4d5 5s2 |
| Electrons per shell | 2, 8, 18, 13, 2 |
| **Physical properties** | |
| [**Phase**](https://en.wikipedia.org/wiki/Phase_(matter)) **at**[**STP**](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure) | [solid](https://en.wikipedia.org/wiki/Solid) |
| [**Melting point**](https://en.wikipedia.org/wiki/Melting_point) | 2430 [K](https://en.wikipedia.org/wiki/Kelvin) ​(2157 °C, ​3915 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 4538 K ​(4265 °C, ​7709 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 11 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 33.29 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 585.2 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 24.27 J/(mol·K) |
| [**Vapor pressure**](https://en.wikipedia.org/wiki/Vapor_pressure) *(extrapolated)*   |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | | ***P***(Pa) | **1** | **10** | **100** | **1 k** | **10 k** | **100 k** | | **at *T***(K) | 2727 | 2998 | 3324 | 3726 | 4234 | 4894 | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | −3, +3,[[1]](https://en.wikipedia.org/wiki/Technetium#cite_note-OpenMOPAC-1) +2, +1,[[1]](https://en.wikipedia.org/wiki/Technetium#cite_note-OpenMOPAC-1) **+4**, +5, +6, **+7** (a strongly [acidic](https://en.wikipedia.org/wiki/Acidic) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 1.9 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 702 kJ/mol * 2nd: 1470 kJ/mol * 3rd: 2850 kJ/mol |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 136 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 147±7 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Technetium_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of technetium** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | ​[hexagonal close-packed](https://en.wikipedia.org/wiki/Close-packing_of_equal_spheres) (hcp)  [Hexagonal close packed crystal structure for technetium](https://en.wikipedia.org/wiki/File:Hexagonal_close_packed.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 16,200 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 7.1 µm/(m·K)[[2]](https://en.wikipedia.org/wiki/Technetium#cite_note-2) (at r.t.) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 50.6 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 200 nΩ·m (at 20 °C) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [Paramagnetic](https://en.wikipedia.org/wiki/Paramagnetic) |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | +270.0·10−6 cm3/mol (298 K)[[3]](https://en.wikipedia.org/wiki/Technetium#cite_note-3) |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-26-8 |
| **History** | |
| **Prediction** | [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) (1871) |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) **and first isolation** | [Emilio Segrè](https://en.wikipedia.org/wiki/Emilio_Segr%C3%A8) and [Carlo Perrier](https://en.wikipedia.org/wiki/Carlo_Perrier) (1937) |
| **Main** [**isotopes of technetium**](https://en.wikipedia.org/wiki/Isotopes_of_technetium) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**Iso­tope**](https://en.wikipedia.org/wiki/Isotope) | [**Abun­dance**](https://en.wikipedia.org/wiki/Natural_abundance) | [**Half-life**](https://en.wikipedia.org/wiki/Half-life) **(*t*1/2)** | [**Decay mode**](https://en.wikipedia.org/wiki/Radioactive_decay) | [**Pro­duct**](https://en.wikipedia.org/wiki/Decay_product) | | **95mTc** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 61 d | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [95Mo](https://en.wikipedia.org/wiki/Molybdenum-95) | | [γ](https://en.wikipedia.org/wiki/Gamma_radiation) | – | | [IT](https://en.wikipedia.org/wiki/Internal_conversion) | 95Tc | | **96Tc** | syn | 4.3 d | ε | [96Mo](https://en.wikipedia.org/wiki/Molybdenum-96) | | γ | – | | **97Tc** | syn | 2.6×106 y | ε | [97Mo](https://en.wikipedia.org/wiki/Molybdenum-97) | | **97mTc** | syn | 91 d | IT | 97Tc | | **98Tc** | syn | 4.2×106 y | [β−](https://en.wikipedia.org/wiki/Beta_emission) | [98Ru](https://en.wikipedia.org/wiki/Ruthenium-98) | | γ | – | | [**99Tc**](https://en.wikipedia.org/wiki/Technetium-99) | [trace](https://en.wikipedia.org/wiki/Trace_radioisotope) | 2.111×105 y | β− | [99Ru](https://en.wikipedia.org/wiki/Ruthenium-99) | | **99**[**m**](https://en.wikipedia.org/wiki/Nuclear_isomer)**Tc** | syn | 6.01 h | IT | 99Tc | | γ | – | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_technetium) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_technetium) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_technetium&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Technetium** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol **Tc** and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 43. It is the lightest element whose isotopes are all [radioactive](https://en.wikipedia.org/wiki/Radioactive); none are [stable](https://en.wikipedia.org/wiki/Stable_nuclide), excluding the fully ionized state of 97Tc.[[4]](https://en.wikipedia.org/wiki/Technetium#cite_note-Takahashi_et_al-4) Nearly all technetium is produced synthetically, and only about 18000 tons can be found at any given time in the Earth's crust. Naturally occurring technetium is a spontaneous [fission product](https://en.wikipedia.org/wiki/Fission_product) in [uranium ore](https://en.wikipedia.org/wiki/Uranium_ore) and [thorium](https://en.wikipedia.org/wiki/Thorium) ore, the most common source, or the product of [neutron capture](https://en.wikipedia.org/wiki/Neutron_capture) in [molybdenum](https://en.wikipedia.org/wiki/Molybdenum) ores. This silvery gray, crystalline [transition metal](https://en.wikipedia.org/wiki/Transition_metal) lies between [rhenium](https://en.wikipedia.org/wiki/Rhenium) and [manganese](https://en.wikipedia.org/wiki/Manganese) in [group 7](https://en.wikipedia.org/wiki/Group_7_element) of the [periodic table](https://en.wikipedia.org/wiki/Periodic_table), and its chemical properties are intermediate between those of these two adjacent elements. The most common naturally occurring isotope is 99Tc.

Many of technetium's properties were predicted by [Dmitri Mendeleev](https://en.wikipedia.org/wiki/Dmitri_Mendeleev) before the element was discovered. Mendeleev noted a gap in his periodic table and gave the undiscovered element the provisional name [*ekamanganese*](https://en.wikipedia.org/wiki/Mendeleev%27s_predicted_elements) (*Em*). In 1937, technetium (specifically the [technetium-97](https://en.wikipedia.org/wiki/Technetium-97) isotope) became the first predominantly artificial element to be produced, hence its name (from the Greek τεχνητός, meaning "synthetic or artificial", + [*-ium*](https://en.wiktionary.org/wiki/-ium#Suffix)).

One short-lived [gamma ray](https://en.wikipedia.org/wiki/Gamma_ray)-emitting [nuclear isomer](https://en.wikipedia.org/wiki/Nuclear_isomer) of technetium—[technetium-99m](https://en.wikipedia.org/wiki/Technetium-99m)—is used in [nuclear medicine](https://en.wikipedia.org/wiki/Nuclear_medicine) for a wide variety of diagnostic tests, such as bone cancer diagnoses. The ground state of this [nuclide](https://en.wikipedia.org/wiki/Nuclide), technetium-99, is used as a gamma-ray-free source of [beta particles](https://en.wikipedia.org/wiki/Beta_particle). Long-lived [technetium isotopes](https://en.wikipedia.org/wiki/Isotopes_of_technetium) produced commercially are by-products of the [fission](https://en.wikipedia.org/wiki/Nuclear_fission) of [uranium-235](https://en.wikipedia.org/wiki/Uranium-235) in [nuclear reactors](https://en.wikipedia.org/wiki/Nuclear_reactor) and are extracted from [nuclear fuel rods](https://en.wikipedia.org/wiki/Nuclear_fuel_cycle). Because no isotope of technetium has a [half-life](https://en.wikipedia.org/wiki/Half-life) longer than 4.2 million years ([technetium-98](https://en.wikipedia.org/wiki/Technetium-98)), the 1952 detection of technetium in [red giants](https://en.wikipedia.org/wiki/Red_giant), helped to prove that stars can produce heavier elements.



**Contents**

* [1 History](https://en.wikipedia.org/wiki/Technetium#History)
  + [1.1 Search for element 43](https://en.wikipedia.org/wiki/Technetium#Search_for_element_43)
  + [1.2 Early misidentifications](https://en.wikipedia.org/wiki/Technetium#Early_misidentifications)
  + [1.3 Irreproducible results](https://en.wikipedia.org/wiki/Technetium#Irreproducible_results)
  + [1.4 Official discovery and later history](https://en.wikipedia.org/wiki/Technetium#Official_discovery_and_later_history)
* [2 Characteristics](https://en.wikipedia.org/wiki/Technetium#Characteristics)
  + [2.1 Physical properties](https://en.wikipedia.org/wiki/Technetium#Physical_properties)
  + [2.2 Chemical properties](https://en.wikipedia.org/wiki/Technetium#Chemical_properties)
* [3 Compounds](https://en.wikipedia.org/wiki/Technetium#Compounds)
  + [3.1 Pertechnetate and derivatives](https://en.wikipedia.org/wiki/Technetium#Pertechnetate_and_derivatives)
  + [3.2 Other chalcogenide derivatives](https://en.wikipedia.org/wiki/Technetium#Other_chalcogenide_derivatives)
  + [3.3 Simple hydride and halide complexes](https://en.wikipedia.org/wiki/Technetium#Simple_hydride_and_halide_complexes)
  + [3.4 Coordination and organometallic complexes](https://en.wikipedia.org/wiki/Technetium#Coordination_and_organometallic_complexes)
  + [3.5 Isotopes](https://en.wikipedia.org/wiki/Technetium#Isotopes)
* [4 Occurrence and production](https://en.wikipedia.org/wiki/Technetium#Occurrence_and_production)
  + [4.1 Fission waste product](https://en.wikipedia.org/wiki/Technetium#Fission_waste_product)
  + [4.2 Fission product for commercial use](https://en.wikipedia.org/wiki/Technetium#Fission_product_for_commercial_use)
  + [4.3 Waste disposal](https://en.wikipedia.org/wiki/Technetium#Waste_disposal)
  + [4.4 Neutron activation](https://en.wikipedia.org/wiki/Technetium#Neutron_activation)
  + [4.5 Particle accelerators](https://en.wikipedia.org/wiki/Technetium#Particle_accelerators)
* [5 Applications](https://en.wikipedia.org/wiki/Technetium#Applications)
  + [5.1 Nuclear medicine and biology](https://en.wikipedia.org/wiki/Technetium#Nuclear_medicine_and_biology)
  + [5.2 Industrial and chemical](https://en.wikipedia.org/wiki/Technetium#Industrial_and_chemical)
* [6 Precautions](https://en.wikipedia.org/wiki/Technetium#Precautions)
* [7 Notes](https://en.wikipedia.org/wiki/Technetium#Notes)
* [8 References](https://en.wikipedia.org/wiki/Technetium#References)
* [9 Bibliography](https://en.wikipedia.org/wiki/Technetium#Bibliography)
* [10 Further reading](https://en.wikipedia.org/wiki/Technetium#Further_reading)
* [11 External links](https://en.wikipedia.org/wiki/Technetium#External_links)

**History**

**Search for element 43**

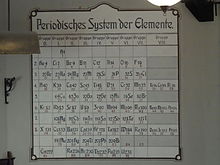
From the 1860s through 1871, early forms of the periodic table proposed by Dmitri Mendeleev contained a gap between [molybdenum](https://en.wikipedia.org/wiki/Molybdenum) (element 42) and [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) (element 44). In 1871, Mendeleev predicted this missing element would occupy the empty place below [manganese](https://en.wikipedia.org/wiki/Manganese) and have similar chemical properties. Mendeleev gave it the provisional name *ekamanganese* (from *eka*-, the [Sanskrit](https://en.wikipedia.org/wiki/Sanskrit) word for *one)* because the predicted element was one place down from the known element manganese.[[5]](https://en.wikipedia.org/wiki/Technetium#cite_note-5)

**Early misidentifications**

Many early researchers, both before and after the periodic table was published, were eager to be the first to discover and name the missing element. Its location in the table suggested that it should be easier to find than other undiscovered elements.

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Claimant** | **Suggested name** | **Actual material** |
| 1828 | [Gottfried Osann](https://en.wikipedia.org/wiki/Gottfried_Osann) | [Polinium](https://en.wikipedia.org/wiki/Polinium) | [Iridium](https://en.wikipedia.org/wiki/Iridium) |
| 1846 | R. Hermann | [Ilmenium](https://en.wikipedia.org/wiki/Ilmenium) | [Niobium](https://en.wikipedia.org/wiki/Niobium)-[tantalum](https://en.wikipedia.org/wiki/Tantalum) [alloy](https://en.wikipedia.org/wiki/Alloy) |
| 1847 | [Heinrich Rose](https://en.wikipedia.org/wiki/Heinrich_Rose) | [Pelopium](https://en.wikipedia.org/wiki/Pelopium)[[6]](https://en.wikipedia.org/wiki/Technetium#cite_note-history-origin-6) | Niobium-tantalum alloy |
| 1877 | Serge Kern | [Davyum](https://en.wikipedia.org/wiki/Davyum) | [Iridium](https://en.wikipedia.org/wiki/Iridium)-[rhodium](https://en.wikipedia.org/wiki/Rhodium)-[iron](https://en.wikipedia.org/wiki/Iron) alloy |
| 1896 | Prosper Barrière | [Lucium](https://en.wikipedia.org/wiki/Lucium) | [Yttrium](https://en.wikipedia.org/wiki/Yttrium) |
| 1908 | [Masataka Ogawa](https://en.wikipedia.org/wiki/Masataka_Ogawa) | [Nipponium](https://en.wikipedia.org/wiki/Nipponium) | [Rhenium](https://en.wikipedia.org/wiki/Rhenium), which was the then unknown dvi-manganese[[7]](https://en.wikipedia.org/wiki/Technetium#cite_note-7) |

**Irreproducible results**

[](https://en.wikipedia.org/wiki/File:Periodisches_System_der_Elemente_(1904-1945,_now_Gdansk_University_of_Technology).jpg)

Periodisches System der Elemente (1904–1945, now at the [Gdańsk University of Technology](https://en.wikipedia.org/wiki/Gda%C5%84sk_University_of_Technology)): lack of elements: 84 polonium Po (though discovered as early as in 1898 by [Maria Sklodowska-Curie](https://en.wikipedia.org/wiki/Marie_Curie)), 85 astatine At (1940, in Berkeley), 87 francium Fr (1939, in France), 93 neptunium Np (1940, in Berkeley) and other actinides and lanthanides. Old symbols for: 18 argon Ar (here: A), 43 technetium Tc (Ma, masurium, 1925, dismissed as an error and finally confirmed in 1937, Palermo), 54 xenon Xe (X), 86 radon, Rn (Em, emanation)

German chemists [Walter Noddack](https://en.wikipedia.org/wiki/Walter_Noddack), [Otto Berg](https://en.wikipedia.org/wiki/Otto_Berg_(scientist)), and [Ida Tacke](https://en.wikipedia.org/wiki/Ida_Tacke) reported the discovery of element 75 and element 43 in 1925, and named element 43 [*masurium*](https://en.wikipedia.org/wiki/Masurium) (after [Masuria](https://en.wikipedia.org/wiki/Masuria) in eastern [Prussia](https://en.wikipedia.org/wiki/Prussia), now in [Poland](https://en.wikipedia.org/wiki/Poland), the region where Walter Noddack's family originated).[[8]](https://en.wikipedia.org/wiki/Technetium#cite_note-multidict-8) The group bombarded [columbite](https://en.wikipedia.org/wiki/Ferrocolumbite) with a beam of [electrons](https://en.wikipedia.org/wiki/Electron) and deduced element 43 was present by examining [X-ray](https://en.wikipedia.org/wiki/X-ray) diffraction [spectrograms](https://en.wikipedia.org/wiki/Spectrogram).[[9]](https://en.wikipedia.org/wiki/Technetium#cite_note-Emsley2001p423-9) The [wavelength](https://en.wikipedia.org/wiki/Wavelength) of the X-rays produced is related to the atomic number by a formula derived by [Henry Moseley](https://en.wikipedia.org/wiki/Henry_Moseley) in 1913. The team claimed to detect a faint X-ray signal at a wavelength produced by element 43. Later experimenters could not replicate the discovery, and it was dismissed as an error for many years.[[10]](https://en.wikipedia.org/wiki/Technetium#cite_note-armstrong-10)[[11]](https://en.wikipedia.org/wiki/Technetium#cite_note-11) Still, in 1933, a series of articles on the discovery of elements quoted the name *masurium* for element 43.[[12]](https://en.wikipedia.org/wiki/Technetium#cite_note-12)[[note 1]](https://en.wikipedia.org/wiki/Technetium#cite_note-13) Whether the 1925 team actually did discover element 43 is still debated.[[13]](https://en.wikipedia.org/wiki/Technetium#cite_note-14)

**Official discovery and later history**

The [discovery](https://en.wikipedia.org/wiki/Discovery_of_the_chemical_elements) of element 43 was finally confirmed in a 1937 experiment at the [University of Palermo](https://en.wikipedia.org/wiki/University_of_Palermo) in Sicily by [Carlo Perrier](https://en.wikipedia.org/wiki/Carlo_Perrier) and [Emilio Segrè](https://en.wikipedia.org/wiki/Emilio_Segr%C3%A8).[[14]](https://en.wikipedia.org/wiki/Technetium#cite_note-Heiserman1992p164-15) In mid-1936, Segrè visited the United States, first [Columbia University](https://en.wikipedia.org/wiki/Columbia_University) in New York and then the [Lawrence Berkeley National Laboratory](https://en.wikipedia.org/wiki/Lawrence_Berkeley_National_Laboratory) in California. He persuaded [cyclotron](https://en.wikipedia.org/wiki/Cyclotron) inventor [Ernest Lawrence](https://en.wikipedia.org/wiki/Ernest_Lawrence) to let him take back some discarded cyclotron parts that had become [radioactive](https://en.wikipedia.org/wiki/Radioactive). Lawrence mailed him a [molybdenum](https://en.wikipedia.org/wiki/Molybdenum) foil that had been part of the deflector in the cyclotron.[[15]](https://en.wikipedia.org/wiki/Technetium#cite_note-16)

Segrè enlisted his colleague Perrier to attempt to prove, through comparative chemistry, that the molybdenum activity was indeed from an element with the atomic number 43. In 1937 they succeeded in isolating the [isotopes](https://en.wikipedia.org/wiki/Isotope) [technetium-95m](https://en.wikipedia.org/wiki/Technetium-95) and [technetium-97](https://en.wikipedia.org/wiki/Technetium-97).[[16]](https://en.wikipedia.org/wiki/Technetium#cite_note-segre-17)[[17]](https://en.wikipedia.org/wiki/Technetium#cite_note-blocks-18) University of Palermo officials wanted them to name their discovery "*panormium*", after the [Latin](https://en.wikipedia.org/wiki/Latin) name for [Palermo](https://en.wikipedia.org/wiki/Palermo), *Panormus*. In 1947[[16]](https://en.wikipedia.org/wiki/Technetium#cite_note-segre-17) element 43 was named after the [Greek](https://en.wikipedia.org/wiki/Greek_language) word *τεχνητός*, meaning "artificial", since it was the first element to be artificially produced.[[6]](https://en.wikipedia.org/wiki/Technetium#cite_note-history-origin-6)[[8]](https://en.wikipedia.org/wiki/Technetium#cite_note-multidict-8) Segrè returned to Berkeley and met [Glenn T. Seaborg](https://en.wikipedia.org/wiki/Glenn_T._Seaborg). They isolated the [metastable isotope](https://en.wikipedia.org/wiki/Metastable_isotope) [technetium-99m](https://en.wikipedia.org/wiki/Technetium-99m), which is now used in some ten million medical diagnostic procedures annually.[[18]](https://en.wikipedia.org/wiki/Technetium#cite_note-19)

In 1952, astronomer [Paul W. Merrill](https://en.wikipedia.org/wiki/Paul_W._Merrill) in California detected the [spectral signature](https://en.wikipedia.org/wiki/Emission_spectrum) of technetium (specifically [wavelengths](https://en.wikipedia.org/wiki/Wavelength) of 403.1 [nm](https://en.wikipedia.org/wiki/Nanometre), 423.8 nm, 426.2 nm, and 429.7 nm) in light from [S-type](https://en.wikipedia.org/wiki/Stellar_classification#Class_S) [red giants](https://en.wikipedia.org/wiki/Red_giant).[[19]](https://en.wikipedia.org/wiki/Technetium#cite_note-20) The stars were near the end of their lives, yet were rich in this short-lived element, indicating that it was being produced in the stars by [nuclear reactions](https://en.wikipedia.org/wiki/Nuclear_reaction). This evidence bolstered the hypothesis that heavier elements are the product of [nucleosynthesis](https://en.wikipedia.org/wiki/Nucleosynthesis) in stars.[[17]](https://en.wikipedia.org/wiki/Technetium#cite_note-blocks-18) More recently, such observations provided evidence that elements are formed by [neutron capture](https://en.wikipedia.org/wiki/Neutron_capture) in the [s-process](https://en.wikipedia.org/wiki/S-process).[[20]](https://en.wikipedia.org/wiki/Technetium#cite_note-s8-21)

Since that discovery, there have been many searches in terrestrial materials for natural sources of technetium. In 1962, technetium-99 was isolated and identified in [pitchblende](https://en.wikipedia.org/wiki/Uraninite) from the [Belgian Congo](https://en.wikipedia.org/wiki/Belgian_Congo) in extremely small quantities (about 0.2 ng/kg);[[20]](https://en.wikipedia.org/wiki/Technetium#cite_note-s8-21) there it originates as a [spontaneous fission](https://en.wikipedia.org/wiki/Spontaneous_fission) product of [uranium-238](https://en.wikipedia.org/wiki/Uranium-238). The [Oklo](https://en.wikipedia.org/wiki/Oklo) [natural nuclear fission reactor](https://en.wikipedia.org/wiki/Natural_nuclear_fission_reactor) contains evidence that significant amounts of technetium-99 were produced and have since decayed into [ruthenium-99](https://en.wikipedia.org/wiki/Ruthenium-99).[[20]](https://en.wikipedia.org/wiki/Technetium#cite_note-s8-21)

**Characteristics**

**Physical properties**

Technetium is a silvery-gray radioactive [metal](https://en.wikipedia.org/wiki/Metal) with an appearance similar to [platinum](https://en.wikipedia.org/wiki/Platinum), commonly obtained as a gray powder.[[21]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRC-22) The [crystal structure](https://en.wikipedia.org/wiki/Crystal_structure) of the pure metal is [hexagonal](https://en.wikipedia.org/wiki/Hexagonal_crystal_system) [close-packed](https://en.wikipedia.org/wiki/Close-packed). Atomic technetium has characteristic [emission lines](https://en.wikipedia.org/wiki/Emission_spectrum) at these [wavelengths](https://en.wikipedia.org/wiki/Wavelength) of light: 363.3 [nm](https://en.wikipedia.org/wiki/Nanometre), 403.1 nm, 426.2 nm, 429.7 nm, and 485.3 nm.[[22]](https://en.wikipedia.org/wiki/Technetium#cite_note-23)

The metal form is slightly [paramagnetic](https://en.wikipedia.org/wiki/Paramagnetism), meaning its [magnetic dipoles](https://en.wikipedia.org/wiki/Dipole) align with external [magnetic fields](https://en.wikipedia.org/wiki/Magnetic_field), but will assume random orientations once the field is removed.[[23]](https://en.wikipedia.org/wiki/Technetium#cite_note-enc-24) Pure, metallic, single-crystal technetium becomes a [type-II superconductor](https://en.wikipedia.org/wiki/Type-II_superconductor) at temperatures below 7.46 [K](https://en.wikipedia.org/wiki/Kelvin).[[note 2]](https://en.wikipedia.org/wiki/Technetium#cite_note-25)[[24]](https://en.wikipedia.org/wiki/Technetium#cite_note-:0-26) Below this temperature, technetium has a very high [magnetic penetration depth](https://en.wikipedia.org/wiki/London_penetration_depth), greater than any other element except [niobium](https://en.wikipedia.org/wiki/Niobium).[[25]](https://en.wikipedia.org/wiki/Technetium#cite_note-27)

**Chemical properties**

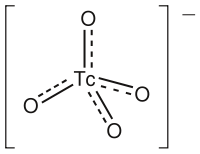
Technetium is located in the [seventh group](https://en.wikipedia.org/wiki/Group_7_element) of the periodic table, between [rhenium](https://en.wikipedia.org/wiki/Rhenium) and [manganese](https://en.wikipedia.org/wiki/Manganese). As predicted by the [periodic law](https://en.wikipedia.org/wiki/History_of_the_periodic_table), its chemical properties are between those two elements. Of the two, technetium more closely resembles rhenium, particularly in its chemical inertness and tendency to form [covalent bonds](https://en.wikipedia.org/wiki/Covalent_bond).[[26]](https://en.wikipedia.org/wiki/Technetium#cite_note-28) Unlike manganese, technetium does not readily form [cations](https://en.wikipedia.org/wiki/Cation) ([ions](https://en.wikipedia.org/wiki/Ion) with a net positive charge). Technetium exhibits nine [oxidation states](https://en.wikipedia.org/wiki/Oxidation_state) from −1 to +7, with +4, +5, and +7 being the most common.[[27]](https://en.wikipedia.org/wiki/Technetium#cite_note-LANL-29) Technetium dissolves in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia), [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid), and concentrated [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid), but it is not soluble in [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid) of any concentration.[[21]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRC-22)

Metallic technetium slowly [tarnishes](https://en.wikipedia.org/wiki/Tarnish) in moist air[[27]](https://en.wikipedia.org/wiki/Technetium#cite_note-LANL-29) and, in powder form, burns in [oxygen](https://en.wikipedia.org/wiki/Oxygen).

Technetium can catalyse the destruction of [hydrazine](https://en.wikipedia.org/wiki/Hydrazine) by [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid), and this property is due to its multiplicity of valencies.[[28]](https://en.wikipedia.org/wiki/Technetium#cite_note-30) This caused a problem in the separation of plutonium from uranium in [nuclear fuel processing](https://en.wikipedia.org/wiki/Nuclear_reprocessing), where hydrazine is used as a protective reductant to keep plutonium in the trivalent rather than the more stable tetravalent state. The problem was exacerbated by the mutually-enhanced solvent extraction of technetium and zirconium at the previous stage,[[29]](https://en.wikipedia.org/wiki/Technetium#cite_note-31) and required a process modification.

**Compounds**

**Pertechnetate and derivatives**

[](https://en.wikipedia.org/wiki/File:Pertechnetate1.svg)

Pertechnetate is one of the most available forms of technetium. It is structurally related to [permanganate](https://en.wikipedia.org/wiki/Permanganate).

The most prevalent form of technetium that is easily accessible is sodium pertechnetate, Na[TcO4]. The majority of this material is produced by radioactive decay from [99MoO4]2−:[[30]](https://en.wikipedia.org/wiki/Technetium#cite_note-32)[[31]](https://en.wikipedia.org/wiki/Technetium#cite_note-nuclmed-33)

[99MoO4]2− → [99TcO4]− + γ

[Pertechnetate](https://en.wikipedia.org/wiki/Pertechnetate) (tetroxidotechnetate) TcO−  
4 behaves analogously to perchlorate, both of which are [tetrahedral](https://en.wikipedia.org/wiki/Tetrahedral_molecular_geometry). Unlike [permanganate](https://en.wikipedia.org/wiki/Permanganate) (MnO−  
4), it is only a weak oxidizing agent.

Related to pertechnetate is [heptoxide](https://en.wikipedia.org/wiki/Technetium(VII)_oxide). This pale-yellow, volatile solid is produced by oxidation of Tc metal and related precursors:

4 Tc + 7 O2 → 2 Tc2O7

It is a very rare example of a molecular metal oxide, other examples being [OsO4](https://en.wikipedia.org/wiki/OsO4) and [RuO4](https://en.wikipedia.org/wiki/RuO4). It adopts a [centrosymmetric](https://en.wikipedia.org/wiki/Centrosymmetry) structure with two types of Tc−O bonds with 167 and 184 pm bond lengths.[[32]](https://en.wikipedia.org/wiki/Technetium#cite_note-34)

Technetium heptoxide hydrolyzes to [pertechnetate](https://en.wikipedia.org/wiki/Pertechnetate) and [pertechnetic acid](https://en.wikipedia.org/wiki/Pertechnetic_acid), depending on the pH:[[33]](https://en.wikipedia.org/wiki/Technetium#cite_note-35)

[[34]](https://en.wikipedia.org/wiki/Technetium#cite_note-36)

Tc2O7 + 2 OH− → 2 TcO4− + H2O

Tc2O7 + H2O → 2 HTcO4

HTcO4 is a strong acid. In concentrated [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid), [TcO4]− converts to the octahedral form TcO3(OH)(H2O)2, the conjugate base of the hypothetical tri[aquo complex](https://en.wikipedia.org/wiki/Aquo_complex) [TcO3(H2O)3]+.[[35]](https://en.wikipedia.org/wiki/Technetium#cite_note-37)

**Other chalcogenide derivatives**

Technetium forms a dioxide,[[36]](https://en.wikipedia.org/wiki/Technetium#cite_note-38) [disulfide](https://en.wikipedia.org/wiki/Metal_dichalcogenide), di[selenide](https://en.wikipedia.org/wiki/Selenide), and di[telluride](https://en.wikipedia.org/wiki/Telluride_(chemistry)). An ill-defined Tc2S7 forms upon treating [pertechnate](https://en.wikipedia.org/wiki/Pertechnate) with hydrogen sulfide. It thermally decomposes into disulfide and elemental sulfur.[[37]](https://en.wikipedia.org/wiki/Technetium#cite_note-39) Similarly the dioxide can be produced by reduction of the Tc2O7.

Unlike the case for rhenium, a trioxide has not been isolated for technetium. However, TcO3 has been identified in the gas phase using [mass spectrometry](https://en.wikipedia.org/wiki/Mass_spectrometry).[[38]](https://en.wikipedia.org/wiki/Technetium#cite_note-40)

**Simple hydride and halide complexes**

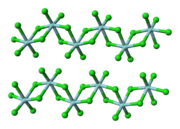
Technetium forms the simple complex TcH2−  
9. The potassium salt is [isostructural](https://en.wikipedia.org/wiki/Isostructural) with [ReH2−  
9](https://en.wikipedia.org/wiki/Potassium_nonahydridorhenate).[[39]](https://en.wikipedia.org/wiki/Technetium#cite_note-41)

The following binary (containing only two elements) technetium halides are known: [TcF6](https://en.wikipedia.org/wiki/TcF6), TcF5, [TcCl4](https://en.wikipedia.org/wiki/TcCl4), TcBr4, TcBr3, α-TcCl3, β-TcCl3, TcI3, α-TcCl2, and β-TcCl2. The [oxidation states](https://en.wikipedia.org/wiki/Oxidation_state) range from Tc(VI) to Tc(II). Technetium halides exhibit different structure types, such as molecular octahedral complexes, extended chains, layered sheets, and metal clusters arranged in a three-dimensional network.[[40]](https://en.wikipedia.org/wiki/Technetium#cite_note-42)[[41]](https://en.wikipedia.org/wiki/Technetium#cite_note-AS-43) These compounds are produced by combining the metal and halogen or by less direct reactions.

TcCl4 is obtained by chlorination of Tc metal or Tc2O7 Upon heating, TcCl4 gives the corresponding Tc(III) and Tc(II) chlorides.[[41]](https://en.wikipedia.org/wiki/Technetium#cite_note-AS-43)

TcCl4 → α-TcCl3 + 1/2 Cl2

TcCl3 → β-TcCl2 + 1/2 Cl2

[](https://en.wikipedia.org/wiki/File:Zirconium-tetrachloride-3D-balls-A.png)

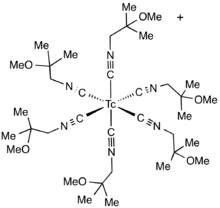
TcCl4 forms chain-like structures, similar to the behavior of several other metal tetrachlorides.

The structure of TcCl4 is composed of infinite zigzag chains of edge-sharing TcCl6 octahedra. It is isomorphous to transition metal tetrachlorides of [zirconium](https://en.wikipedia.org/wiki/Zirconium), [hafnium](https://en.wikipedia.org/wiki/Hafnium), and [platinum](https://en.wikipedia.org/wiki/Platinum).[[41]](https://en.wikipedia.org/wiki/Technetium#cite_note-AS-43)

Two polymorphs of technetium trichloride exist, α- and β-TcCl3. The α polymorph is also denoted as Tc3Cl9. It adopts a confacial [bioctahedral structure](https://en.wikipedia.org/wiki/Octahedral_molecular_geometry#Bioctahedral_molecular_geometry).[[42]](https://en.wikipedia.org/wiki/Technetium#cite_note-44) It is prepared by treating the chloro-acetate Tc2(O2CCH3)4Cl2 with HCl. Like [Re3Cl9](https://en.wikipedia.org/wiki/Trirhenium_nonachloride), the structure of the α-polymorph consists of triangles with short M-M distances. β-TcCl3 features octahedral Tc centers, which are organized in pairs, as seen also for [molybdenum trichloride](https://en.wikipedia.org/wiki/Molybdenum_trichloride). TcBr3 does not adopt the structure of either trichloride phase. Instead it has the structure of [molybdenum tribromide](https://en.wikipedia.org/wiki/Molybdenum_tribromide), consisting of chains of confacial octahedra with alternating short and long Tc—Tc contacts. TcI3 has the same structure as the high temperature phase of [TiI3](https://en.wikipedia.org/wiki/Titanium(III)_iodide), featuring chains of confacial octahedra with equal Tc—Tc contacts.[[41]](https://en.wikipedia.org/wiki/Technetium#cite_note-AS-43)

Several anionic technetium halides are known. The binary tetrahalides can be converted to the hexahalides [TcX6]2− (X = F, Cl, Br, I), which adopt [octahedral molecular geometry](https://en.wikipedia.org/wiki/Octahedral_molecular_geometry).[[20]](https://en.wikipedia.org/wiki/Technetium#cite_note-s8-21) More reduced halides form anionic clusters with Tc–Tc bonds. The situation is similar for the related elements of Mo, W, Re. These clusters have the nuclearity Tc4, Tc6, Tc8, and Tc13. The more stable Tc6 and Tc8 clusters have prism shapes where vertical pairs of Tc atoms are connected by triple bonds and the planar atoms by single bonds. Every technetium atom makes six bonds, and the remaining valence electrons can be saturated by one axial and two [bridging ligand](https://en.wikipedia.org/wiki/Bridging_ligand) halogen atoms such as [chlorine](https://en.wikipedia.org/wiki/Chlorine) or [bromine](https://en.wikipedia.org/wiki/Bromine).[[43]](https://en.wikipedia.org/wiki/Technetium#cite_note-45)

**Coordination and organometallic complexes**

[](https://en.wikipedia.org/wiki/File:Tc_CNCH2CMe2(OMe)_6Cation.png)

[Technetium (99mTc) sestamibiis](https://en.wikipedia.org/wiki/Technetium_(99mTc)_sestamibi) ("Cardiolite") widely used for imaging of the heart.

Technetium forms a variety of [coordination complexes](https://en.wikipedia.org/wiki/Coordination_complex) with organic ligands. Many have been well-investigated because of their relevance to nuclear medicine.[[44]](https://en.wikipedia.org/wiki/Technetium#cite_note-46)

Technetium forms a variety of compounds with Tc–C bonds, i.e. organotechnetium complexes. Prominent members of this class are complexes with CO, arene, and cyclopentadienyl ligands.[[45]](https://en.wikipedia.org/wiki/Technetium#cite_note-Alberto-47) The binary carbonyl Tc2(CO)10 is a white volatile solid.[[46]](https://en.wikipedia.org/wiki/Technetium#cite_note-48) In this molecule, two technetium atoms are bound to each other; each atom is surrounded by [octahedra](https://en.wikipedia.org/wiki/Octahedron) of five carbonyl ligands. The bond length between technetium atoms, 303 pm,[[47]](https://en.wikipedia.org/wiki/Technetium#cite_note-49)[[48]](https://en.wikipedia.org/wiki/Technetium#cite_note-50) is significantly larger than the distance between two atoms in metallic technetium (272 pm). Similar [carbonyls](https://en.wikipedia.org/wiki/Carbonyl) are formed by technetium's [congeners](https://en.wikipedia.org/wiki/Congener_(chemistry)), manganese and rhenium.[[49]](https://en.wikipedia.org/wiki/Technetium#cite_note-51) Interest in organotechnetium compounds has also been motivated by applications in [nuclear medicine](https://en.wikipedia.org/wiki/Nuclear_medicine).[[45]](https://en.wikipedia.org/wiki/Technetium#cite_note-Alberto-47) Unusual for other metal carbonyls, Tc forms aquo-carbonyl complexes, prominent being [Tc(CO)3(H2O)3]+.[[45]](https://en.wikipedia.org/wiki/Technetium#cite_note-Alberto-47)

**Isotopes**

Main article: [Isotopes of technetium](https://en.wikipedia.org/wiki/Isotopes_of_technetium)

Technetium, with [atomic number](https://en.wikipedia.org/wiki/Atomic_number) (denoted *Z*) 43, is the lowest-numbered element in the periodic table of which all isotopes are [radioactive](https://en.wikipedia.org/wiki/Radioactive). The second-lightest exclusively radioactive element, [promethium](https://en.wikipedia.org/wiki/Promethium), has an atomic number of 61.[[27]](https://en.wikipedia.org/wiki/Technetium#cite_note-LANL-29) [Atomic nuclei](https://en.wikipedia.org/wiki/Atomic_nucleus) with an odd number of [protons](https://en.wikipedia.org/wiki/Proton) are less stable than those with even numbers, even when the total number of [nucleons](https://en.wikipedia.org/wiki/Nucleon) (protons + [neutrons](https://en.wikipedia.org/wiki/Neutron)) is even,[[50]](https://en.wikipedia.org/wiki/Technetium#cite_note-52) and odd numbered elements have fewer stable [isotopes](https://en.wikipedia.org/wiki/Isotope).

The most stable [radioactive isotopes](https://en.wikipedia.org/wiki/Radionuclide) are technetium-98 with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 4.2 million years ([Ma](https://en.wikipedia.org/wiki/Annum)), technetium-97 with 2.6 Ma, and technetium-99 with 211,000 years.[[51]](https://en.wikipedia.org/wiki/Technetium#cite_note-NNDC-53) Thirty other radioisotopes have been characterized with [mass numbers](https://en.wikipedia.org/wiki/Mass_number) ranging from 85 to 118.[[51]](https://en.wikipedia.org/wiki/Technetium#cite_note-NNDC-53) Most of these have half-lives that are less than an hour, the exceptions being technetium-93 (half-life: 2.73 hours), technetium-94 (half-life: 4.88 hours), technetium-95 (half-life: 20 hours), and technetium-96 (half-life: 4.3 days).[[52]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRCisotopes-54)

The primary [decay mode](https://en.wikipedia.org/wiki/Decay_mode) for isotopes lighter than technetium-98 (98Tc) is [electron capture](https://en.wikipedia.org/wiki/Electron_capture), producing [molybdenum](https://en.wikipedia.org/wiki/Molybdenum) (*Z* = 42).[[51]](https://en.wikipedia.org/wiki/Technetium#cite_note-NNDC-53) For technetium-98 and heavier isotopes, the primary mode is [beta emission](https://en.wikipedia.org/wiki/Beta_decay) (the emission of an [electron](https://en.wikipedia.org/wiki/Electron) or [positron](https://en.wikipedia.org/wiki/Positron)), producing [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) (*Z* = 44), with the exception that technetium-100 can decay both by beta emission and electron capture.[[51]](https://en.wikipedia.org/wiki/Technetium#cite_note-NNDC-53)[[53]](https://en.wikipedia.org/wiki/Technetium#cite_note-55)

Technetium also has numerous [nuclear isomers](https://en.wikipedia.org/wiki/Nuclear_isomer), which are isotopes with one or more [excited](https://en.wikipedia.org/wiki/Excited_state) nucleons. Technetium-97m (97mTc; 'm' stands for [metastability](https://en.wikipedia.org/wiki/Metastability)) is the most stable, with a half-life of 91 days (0.0965 MeV).[[52]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRCisotopes-54) This is followed by technetium-95m (half-life: 61 days, 0.03 MeV), and technetium-99m (half-life: 6.01 hours, 0.142 MeV).[[52]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRCisotopes-54) Technetium-99m emits only [gamma rays](https://en.wikipedia.org/wiki/Gamma_ray) and decays to technetium-99.[[52]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRCisotopes-54)

Technetium-99 (99Tc) is a major product of the fission of uranium-235 (235U), making it the most common and most readily available isotope of technetium. One gram of technetium-99 produces 6.2×108 disintegrations a second (that is, 0.62 G[Bq](https://en.wikipedia.org/wiki/Becquerel)/g).[[23]](https://en.wikipedia.org/wiki/Technetium#cite_note-enc-24)

**Occurrence and production**

Technetium occurs naturally in the Earth's [crust](https://en.wikipedia.org/wiki/Crust_(geology)) in minute concentrations of about 0.003 parts per trillion. This totals about 18000 tonnes at any given time, assuming the mass of the Earth's crust is 6×1021 kilograms. Technetium is so rare because technetium-98's [half-life](https://en.wikipedia.org/wiki/Half-life) is only 4.2 million years. More than a thousand of such periods have passed since the formation of the [Earth](https://en.wikipedia.org/wiki/Earth), so the probability for the survival of even one atom of [primordial](https://en.wikipedia.org/wiki/Primordial_nuclide) technetium is effectively zero. However, small amounts exist as spontaneous [fission products](https://en.wikipedia.org/wiki/Fission_product) in [uranium ores](https://en.wikipedia.org/wiki/Uranium_ore). A kilogram of uranium contains an estimated 1 nanogram (10−9 g) of technetium.[[17]](https://en.wikipedia.org/wiki/Technetium#cite_note-blocks-18)[[54]](https://en.wikipedia.org/wiki/Technetium#cite_note-56)[[55]](https://en.wikipedia.org/wiki/Technetium#cite_note-57) Some [red giant](https://en.wikipedia.org/wiki/Red_giant) stars with the spectral types S-, M-, and N contain a spectral absorption line indicating the presence of technetium.[[21]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRC-22)[[56]](https://en.wikipedia.org/wiki/Technetium#cite_note-58) These red-giants are known informally as [technetium stars](https://en.wikipedia.org/wiki/Technetium_star).

**Fission waste product**

In contrast to the rare natural occurrence, bulk quantities of technetium-99 are produced each year from [spent nuclear fuel rods](https://en.wikipedia.org/wiki/Spent_nuclear_fuel), which contain various fission products. The fission of a gram of [uranium-235](https://en.wikipedia.org/wiki/Uranium-235) in [nuclear reactors](https://en.wikipedia.org/wiki/Nuclear_reactor) yields 27 mg of technetium-99, giving technetium a [fission product yield](https://en.wikipedia.org/wiki/Fission_product_yield) of 6.1%.[[23]](https://en.wikipedia.org/wiki/Technetium#cite_note-enc-24) Other [fissile](https://en.wikipedia.org/wiki/Fissile) isotopes produce similar yields of technetium, such as 4.9% from [uranium-233](https://en.wikipedia.org/wiki/Uranium-233) and 6.21% from [plutonium-239](https://en.wikipedia.org/wiki/Plutonium-239).[[57]](https://en.wikipedia.org/wiki/Technetium#cite_note-59) An estimated 49,000 T[Bq](https://en.wikipedia.org/wiki/Becquerel) (78 [metric tons](https://en.wikipedia.org/wiki/Tonne)) of technetium was produced in nuclear reactors between 1983 and 1994, by far the dominant source of terrestrial technetium.[[58]](https://en.wikipedia.org/wiki/Technetium#cite_note-yoshihara-60)[[59]](https://en.wikipedia.org/wiki/Technetium#cite_note-leon-61) Only a fraction of the production is used commercially.[[note 3]](https://en.wikipedia.org/wiki/Technetium#cite_note-62)

Technetium-99 is produced by the [nuclear fission](https://en.wikipedia.org/wiki/Nuclear_fission) of both uranium-235 and plutonium-239. It is therefore present in [radioactive waste](https://en.wikipedia.org/wiki/Radioactive_waste) and in the [nuclear fallout](https://en.wikipedia.org/wiki/Nuclear_fallout) of [fission bomb](https://en.wikipedia.org/wiki/Nuclear_weapon) explosions. Its decay, measured in [becquerels](https://en.wikipedia.org/wiki/Becquerel) per amount of spent fuel, is the dominant contributor to nuclear waste radioactivity after about 104 to 106 years after the creation of the nuclear waste.[[58]](https://en.wikipedia.org/wiki/Technetium#cite_note-yoshihara-60) From 1945 to 1994, an estimated 160 T[Bq](https://en.wikipedia.org/wiki/Becquerel) (about 250 kg) of technetium-99 was released into the environment during atmospheric [nuclear tests](https://en.wikipedia.org/wiki/Nuclear_test).[[58]](https://en.wikipedia.org/wiki/Technetium#cite_note-yoshihara-60)[[60]](https://en.wikipedia.org/wiki/Technetium#cite_note-63) The amount of technetium-99 from nuclear reactors released into the environment up to 1986 is on the order of 1000 TBq (about 1600 kg), primarily by [nuclear fuel reprocessing](https://en.wikipedia.org/wiki/Nuclear_fuel_reprocessing); most of this was discharged into the sea. Reprocessing methods have reduced emissions since then, but as of 2005 the primary release of technetium-99 into the environment is by the [Sellafield](https://en.wikipedia.org/wiki/Sellafield) plant, which released an estimated 550 TBq (about 900 kg) from 1995–1999 into the [Irish Sea](https://en.wikipedia.org/wiki/Irish_Sea).[[59]](https://en.wikipedia.org/wiki/Technetium#cite_note-leon-61) From 2000 onwards the amount has been limited by regulation to 90 TBq (about 140 kg) per year.[[61]](https://en.wikipedia.org/wiki/Technetium#cite_note-64) Discharge of technetium into the sea resulted in contamination of some seafood with minuscule quantities of this element. For example, [European lobster](https://en.wikipedia.org/wiki/European_lobster) and fish from west [Cumbria](https://en.wikipedia.org/wiki/Cumbria) contain about 1 Bq/kg of technetium.[[62]](https://en.wikipedia.org/wiki/Technetium#cite_note-65)[[63]](https://en.wikipedia.org/wiki/Technetium#cite_note-66)[[note 4]](https://en.wikipedia.org/wiki/Technetium#cite_note-67)

**Fission product for commercial use**

The [metastable](https://en.wikipedia.org/wiki/Metastability) isotope technetium-99m is continuously produced as a [fission product](https://en.wikipedia.org/wiki/Fission_product) from the fission of uranium or [plutonium](https://en.wikipedia.org/wiki/Plutonium) in [nuclear reactors](https://en.wikipedia.org/wiki/Nuclear_reactor):

U 92 238 → sf I 53 137 + Y 39 99 + 2 0 1 n {\displaystyle {\ce {^{238}\_{92}U ->[{\ce {sf}}] ^{137}\_{53}I + ^{99}\_{39}Y + 2^{1}\_{0}n}}}

Y 39 99 → 1.47 s β − Zr 40 99 → 2.1 s β − Nb 41 99 → 15.0 s β − Mo 42 99 → 65.94 h β − Tc 43 99 → 211 , 100 y β − Ru 44 99 {\displaystyle {\ce {^{99}\_{39}Y ->[\beta^-][1.47\,{\ce {s}}] ^{99}\_{40}Zr ->[\beta^-][2.1\,{\ce {s}}] ^{99}\_{41}Nb ->[\beta^-][15.0\,{\ce {s}}] ^{99}\_{42}Mo ->[\beta^-][65.94\,{\ce {h}}] ^{99}\_{43}Tc ->[\beta^-][211,100\,{\ce {y}}] ^{99}\_{44}Ru}}}

Because used fuel is allowed to stand for several years before reprocessing, all molybdenum-99 and technetium-99m is decayed by the time that the fission products are separated from the major [actinides](https://en.wikipedia.org/wiki/Actinide) in conventional [nuclear reprocessing](https://en.wikipedia.org/wiki/Nuclear_reprocessing). The liquid left after plutonium–uranium extraction ([PUREX](https://en.wikipedia.org/wiki/PUREX)) contains a high concentration of technetium as TcO−  
4 but almost all of this is technetium-99, not technetium-99m.[[64]](https://en.wikipedia.org/wiki/Technetium#cite_note-68)

The vast majority of the technetium-99m used in medical work is produced by irradiating dedicated [highly enriched uranium](https://en.wikipedia.org/wiki/Enriched_uranium#Highly_enriched_uranium_(HEU)) targets in a reactor, extracting molybdenum-99 from the targets in reprocessing facilities,[[31]](https://en.wikipedia.org/wiki/Technetium#cite_note-nuclmed-33) and recovering at the diagnostic center the technetium-99m produced upon decay of molybdenum-99.[[65]](https://en.wikipedia.org/wiki/Technetium#cite_note-69)[[66]](https://en.wikipedia.org/wiki/Technetium#cite_note-NAS_Report-70) Molybdenum-99 in the form of molybdate MoO2−  
4 is [adsorbed](https://en.wikipedia.org/wiki/Adsorption) onto acid alumina (Al  
2O  
3) in a [shielded](https://en.wikipedia.org/wiki/Radiation_shielding) [column chromatograph](https://en.wikipedia.org/wiki/Column_chromatography) inside a [technetium-99m generator](https://en.wikipedia.org/wiki/Technetium-99m_generator) ("technetium cow", also occasionally called a "molybdenum cow"). Molybdenum-99 has a half-life of 67 hours, so short-lived technetium-99m (half-life: 6 hours), which results from its decay, is being constantly produced.[[17]](https://en.wikipedia.org/wiki/Technetium#cite_note-blocks-18) The soluble [pertechnetate](https://en.wikipedia.org/wiki/Pertechnetate) TcO−  
4 can then be chemically extracted by [elution](https://en.wikipedia.org/wiki/Elution) using a [saline solution](https://en.wikipedia.org/wiki/Saline_solution). A drawback of this process is that it requires targets containing uranium-235, which are subject to the security precautions of fissile materials.[[67]](https://en.wikipedia.org/wiki/Technetium#cite_note-71)[[68]](https://en.wikipedia.org/wiki/Technetium#cite_note-72)

[](https://en.wikipedia.org/wiki/File:First_technetium-99m_generator_-_1958.jpg)

The first technetium-99m generator, unshielded, 1958. A Tc-99m [pertechnetate](https://en.wikipedia.org/wiki/Pertechnetate) solution is being eluted from Mo-99 [molybdate](https://en.wikipedia.org/wiki/Molybdate) bound to a chromatographic substrate

Almost two-thirds of the world's supply comes from two reactors; the [National Research Universal Reactor](https://en.wikipedia.org/wiki/National_Research_Universal_Reactor) at [Chalk River Laboratories](https://en.wikipedia.org/wiki/Chalk_River_Laboratories) in Ontario, Canada, and the [High Flux Reactor](https://en.wikipedia.org/wiki/Petten_nuclear_reactor) at [Nuclear Research and Consultancy Group](https://en.wikipedia.org/wiki/Nuclear_Research_and_Consultancy_Group) in Petten, Netherlands. All major reactors that produce technetium-99m were built in the 1960s and are close to the [end of life](https://en.wikipedia.org/wiki/End-of-life_(product)). The two new Canadian [Multipurpose Applied Physics Lattice Experiment](https://en.wikipedia.org/wiki/Multipurpose_Applied_Physics_Lattice_Experiment) reactors planned and built to produce 200% of the demand of technetium-99m relieved all other producers from building their own reactors. With the cancellation of the already tested reactors in 2008, the future supply of technetium-99m became problematic.[[69]](https://en.wikipedia.org/wiki/Technetium#cite_note-73)

The Chalk River reactor was shut down for maintenance in August 2009, and reopened in August 2010. The Petten reactor had a 6-month scheduled maintenance shutdown on Friday, February 19, 2010, and reopened September 2010.[[70]](https://en.wikipedia.org/wiki/Technetium#cite_note-74) With millions of procedures relying on technetium-99m every year, the low supply has left a gap, leaving some practitioners to revert to techniques not used for 20 years. Somewhat allaying this issue is an announcement from the Polish [Maria research reactor](https://en.wikipedia.org/wiki/Maria_reactor) that they have developed a technique to isolate technetium.[[71]](https://en.wikipedia.org/wiki/Technetium#cite_note-NY_Times-75)

**Waste disposal**

The long half-life of technetium-99 and its potential to form [anionic](https://en.wikipedia.org/wiki/Anionic) species creates a major concern for long-term [disposal of radioactive waste](https://en.wikipedia.org/wiki/High-level_radioactive_waste_management). Many of the processes designed to remove fission products in reprocessing plants aim at [cationic](https://en.wikipedia.org/wiki/Cationic) species such as [caesium](https://en.wikipedia.org/wiki/Caesium) (e.g., [caesium-137](https://en.wikipedia.org/wiki/Caesium-137)) and [strontium](https://en.wikipedia.org/wiki/Strontium) (e.g., [strontium-90](https://en.wikipedia.org/wiki/Strontium-90)). Hence the pertechnetate escapes through those processes. Current disposal options favor [burial](https://en.wikipedia.org/wiki/Geological_repository) in continental, geologically stable rock. The primary danger with such practice is the likelihood that the waste will contact water, which could leach radioactive contamination into the environment. The anionic pertechnetate and [iodide](https://en.wikipedia.org/wiki/Iodide) tend not to adsorb into the surfaces of minerals, and are likely to be washed away. By comparison [plutonium](https://en.wikipedia.org/wiki/Plutonium), [uranium](https://en.wikipedia.org/wiki/Uranium), and [caesium](https://en.wikipedia.org/wiki/Caesium) tend to bind to soil particles. Technetium could be immobilized by some environments, such as microbial activity in lake bottom sediments,[[72]](https://en.wikipedia.org/wiki/Technetium#cite_note-76) and the [**environmental chemistry**](https://en.wikipedia.org/wiki/Environmental_chemistry) of technetium is an area of active research.[[73]](https://en.wikipedia.org/wiki/Technetium#cite_note-77)

An alternative disposal method, [transmutation](https://en.wikipedia.org/wiki/Nuclear_transmutation), has been demonstrated at [CERN](https://en.wikipedia.org/wiki/CERN) for technetium-99. In this process, the technetium (technetium-99 as a metal target) is bombarded with [neutrons](https://en.wikipedia.org/wiki/Neutron) to form the short-lived technetium-100 (half-life = 16 seconds) which decays by beta decay to [ruthenium](https://en.wikipedia.org/wiki/Ruthenium)-100. If recovery of usable ruthenium is a goal, an extremely pure technetium target is needed; if small traces of the [minor actinides](https://en.wikipedia.org/wiki/Minor_actinide) such as [americium](https://en.wikipedia.org/wiki/Americium) and [curium](https://en.wikipedia.org/wiki/Curium) are present in the target, they are likely to undergo fission and form more [fission products](https://en.wikipedia.org/wiki/Fission_product) which increase the radioactivity of the irradiated target. The formation of ruthenium-106 (half-life 374 days) from the 'fresh fission' is likely to increase the activity of the final ruthenium metal, which will then require a longer cooling time after irradiation before the ruthenium can be used.[[74]](https://en.wikipedia.org/wiki/Technetium#cite_note-78)

The actual separation of technetium-99 from spent nuclear fuel is a long process. During [fuel reprocessing](https://en.wikipedia.org/wiki/Nuclear_reprocessing), it comes out as a component of the highly radioactive waste liquid. After sitting for several years, the radioactivity reduces to a level where extraction of the long-lived isotopes, including technetium-99, becomes feasible. A series of chemical processes yields technetium-99 metal of high purity.[[75]](https://en.wikipedia.org/wiki/Technetium#cite_note-79)

**Neutron activation**

[Molybdenum-99](https://en.wikipedia.org/wiki/Molybdenum-99), which decays to form technetium-99m, can be formed by the [neutron activation](https://en.wikipedia.org/wiki/Neutron_activation) of molybdenum-98.[[76]](https://en.wikipedia.org/wiki/Technetium#cite_note-IAEA_TECDOC-1340-80) When needed, other technetium isotopes are not produced in significant quantities by fission, but are manufactured by neutron irradiation of parent isotopes (for example, technetium-97 can be made by neutron irradiation of [ruthenium-96](https://en.wikipedia.org/wiki/Ruthenium-96)).[[77]](https://en.wikipedia.org/wiki/Technetium#cite_note-81)

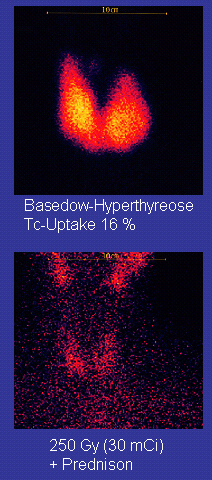
**Particle accelerators**

The feasibility of technetium-99m production with the 22-MeV-proton bombardment of a molybdenum-100 target in medical cyclotrons following the reaction 100Mo(p,2n)99mTc was demonstrated in 1971.[[78]](https://en.wikipedia.org/wiki/Technetium#cite_note-82) The recent shortages of medical technetium-99m reignited the interest in its production by proton bombardment of isotopically-enriched (>99.5%) molybdenum-100 targets.[[79]](https://en.wikipedia.org/wiki/Technetium#cite_note-bbc-20150530-83)[[80]](https://en.wikipedia.org/wiki/Technetium#cite_note-84) Other techniques are being investigated for obtaining molybdenum-99 from molybdenum-100 via (n,2n) or (γ,n) reactions in particle accelerators.[[81]](https://en.wikipedia.org/wiki/Technetium#cite_note-85)[[82]](https://en.wikipedia.org/wiki/Technetium#cite_note-86)[[83]](https://en.wikipedia.org/wiki/Technetium#cite_note-87)

**Applications**

**Nuclear medicine and biology**

Main article: [Technetium-99m](https://en.wikipedia.org/wiki/Technetium-99m)

[](https://en.wikipedia.org/wiki/File:Basedow-vor-nach-RIT.jpg)

Technetium [scintigraphy](https://en.wikipedia.org/wiki/Nuclear_medicine) of a neck of [Graves' disease](https://en.wikipedia.org/wiki/Graves%27_disease) patient

[Technetium-99m](https://en.wikipedia.org/wiki/Technetium-99m) ("m" indicates that this is a [metastable](https://en.wikipedia.org/wiki/Nuclear_isomer#Metastable_isomers) nuclear isomer) is used in radioactive isotope [medical tests](https://en.wikipedia.org/wiki/Nuclear_medicine). For example, Technetium-99m is a [radioactive tracer](https://en.wikipedia.org/wiki/Radioactive_tracer) that medical imaging equipment tracks in the human body.[[17]](https://en.wikipedia.org/wiki/Technetium#cite_note-blocks-18)[[79]](https://en.wikipedia.org/wiki/Technetium#cite_note-bbc-20150530-83) It is well suited to the role because it emits readily detectable 140 [keV](https://en.wikipedia.org/wiki/Electronvolt) [gamma rays](https://en.wikipedia.org/wiki/Gamma_ray), and its half-life is 6.01 hours (meaning that about 94% of it decays to technetium-99 in 24 hours).[[23]](https://en.wikipedia.org/wiki/Technetium#cite_note-enc-24) The chemistry of technetium allows it to be bound to a variety of biochemical compounds, each of which determines how it is metabolized and deposited in the body, and this single isotope can be used for a multitude of diagnostic tests. More than 50 common [radiopharmaceuticals](https://en.wikipedia.org/wiki/Radiopharmaceuticals) are based on technetium-99m for imaging and functional studies of the [brain](https://en.wikipedia.org/wiki/Human_brain), heart muscle, [thyroid](https://en.wikipedia.org/wiki/Thyroid), [lungs](https://en.wikipedia.org/wiki/Human_lung), [liver](https://en.wikipedia.org/wiki/Liver), [gall bladder](https://en.wikipedia.org/wiki/Gall_bladder), [kidneys](https://en.wikipedia.org/wiki/Kidney), [skeleton](https://en.wikipedia.org/wiki/Human_skeleton), [blood](https://en.wikipedia.org/wiki/Blood), and [tumors](https://en.wikipedia.org/wiki/Tumor).[[84]](https://en.wikipedia.org/wiki/Technetium#cite_note-88)

The longer-lived isotope, technetium-95m with a half-life of 61 days, is used as a [radioactive tracer](https://en.wikipedia.org/wiki/Radioactive_tracer) to study the movement of technetium in the environment and in plant and animal systems.[[85]](https://en.wikipedia.org/wiki/Technetium#cite_note-89)

**Industrial and chemical**

Technetium-99 decays almost entirely by beta decay, emitting beta particles with consistent low energies and no accompanying gamma rays. Moreover, its long half-life means that this emission decreases very slowly with time. It can also be extracted to a high chemical and isotopic purity from radioactive waste. For these reasons, it is a [National Institute of Standards and Technology](https://en.wikipedia.org/wiki/National_Institute_of_Standards_and_Technology) (NIST) standard beta emitter, and is used for equipment calibration.[[86]](https://en.wikipedia.org/wiki/Technetium#cite_note-90) Technetium-99 has also been proposed for optoelectronic devices and [nanoscale](https://en.wikipedia.org/wiki/Nanotechnology) [nuclear batteries](https://en.wikipedia.org/wiki/Nuclear_battery).[[87]](https://en.wikipedia.org/wiki/Technetium#cite_note-91)

Like [rhenium](https://en.wikipedia.org/wiki/Rhenium) and [palladium](https://en.wikipedia.org/wiki/Palladium), technetium can serve as a [catalyst](https://en.wikipedia.org/wiki/Catalyst). In processes such as the [dehydrogenation](https://en.wikipedia.org/wiki/Dehydrogenation) of [isopropyl alcohol](https://en.wikipedia.org/wiki/Isopropyl_alcohol), it is a far more effective catalyst than either rhenium or palladium. However, its radioactivity is a major problem in safe catalytic applications.[[88]](https://en.wikipedia.org/wiki/Technetium#cite_note-92)

When steel is immersed in water, adding a small concentration (55 [ppm](https://en.wikipedia.org/wiki/Parts_per_notation)) of potassium pertechnetate(VII) to the water protects the [steel](https://en.wikipedia.org/wiki/Steel) from corrosion, even if the temperature is raised to 250 °C (523 K).[[89]](https://en.wikipedia.org/wiki/Technetium#cite_note-corr-93) For this reason, pertechnetate has been used as an anodic [corrosion](https://en.wikipedia.org/wiki/Corrosion) inhibitor for steel, although technetium's radioactivity poses problems that limit this application to self-contained systems.[[90]](https://en.wikipedia.org/wiki/Technetium#cite_note-94) While (for example) CrO2−  
4 can also inhibit corrosion, it requires a concentration ten times as high. In one experiment, a specimen of carbon steel was kept in an aqueous solution of pertechnetate for 20 years and was still uncorroded.[[89]](https://en.wikipedia.org/wiki/Technetium#cite_note-corr-93) The mechanism by which pertechnetate prevents corrosion is not well understood, but seems to involve the reversible formation of a thin surface layer ([passivation](https://en.wikipedia.org/wiki/Passivation_(chemistry))). One theory holds that the pertechnetate reacts with the steel surface to form a layer of technetium [dioxide](https://en.wikipedia.org/wiki/Oxide) which prevents further corrosion; the same effect explains how iron powder can be used to remove pertechnetate from water. ([Activated carbon](https://en.wikipedia.org/wiki/Activated_carbon) can also be used for the same purpose.) The effect disappears rapidly if the concentration of pertechnetate falls below the minimum concentration or if too high a concentration of other ions is added.[[91]](https://en.wikipedia.org/wiki/Technetium#cite_note-s91-95)

As noted, the radioactive nature of technetium (3 MBq/L at the concentrations required) makes this corrosion protection impractical in almost all situations. Nevertheless, corrosion protection by pertechnetate ions was proposed (but never adopted) for use in [boiling water reactors](https://en.wikipedia.org/wiki/Boiling_water_reactor).[[91]](https://en.wikipedia.org/wiki/Technetium#cite_note-s91-95)

**Precautions**

Technetium plays no natural biological role and is not normally found in the human body.[[21]](https://en.wikipedia.org/wiki/Technetium#cite_note-CRC-22) Technetium is produced in quantity by nuclear fission, and spreads more readily than many radionuclides. It appears to have low chemical toxicity. For example, no significant change in blood formula, body and organ weights, and food consumption could be detected for rats which ingested up to 15 µg of technetium-99 per gram of food for several weeks.[[92]](https://en.wikipedia.org/wiki/Technetium#cite_note-96) The radiological toxicity of technetium (per unit of mass) is a function of compound, type of radiation for the isotope in question, and the isotope's half-life.[[93]](https://en.wikipedia.org/wiki/Technetium#cite_note-97)

All isotopes of technetium must be handled carefully. The most common isotope, technetium-99, is a weak beta emitter; such radiation is stopped by the walls of laboratory glassware. The primary hazard when working with technetium is inhalation of dust; such [radioactive contamination](https://en.wikipedia.org/wiki/Radioactive_contamination) in the lungs can pose a significant cancer risk. For most work, careful handling in a [fume hood](https://en.wikipedia.org/wiki/Fume_hood) is sufficient, and a [glove box](https://en.wikipedia.org/wiki/Glove_box) is not needed.[[94]](https://en.wikipedia.org/wiki/Technetium#cite_note-98)

**Notes**

 In 1998 John T. Armstrong of the [National Institute of Standards and Technology](https://en.wikipedia.org/wiki/National_Institute_of_Standards_and_Technology) ran "computer simulations" of the 1925 experiments and obtained results quite close to those reported by the Noddack team. "Using first-principles X-ray-emission spectral-generation algorithms developed at NIST, I simulated the X-ray spectra that would be expected for Van Assche's initial estimates of the Noddacks' residue compositions. The first results were surprisingly close to their published spectrum! Over the next couple of years, we refined our reconstruction of their analytical methods and performed more sophisticated simulations. The agreement between simulated and reported spectra improved further. Our calculation of the amount of element 43 required to produce their spectrum is quite similar to the direct measurements of natural technetium abundance in uranium ore published in 1999 by Dave Curtis and colleagues at Los Alamos. We can find no other plausible explanation for the Noddacks' data than that they did indeed detect fission "masurium."  
*Armstrong, J. T. (2003).* [*"Technetium"*](http://pubs.acs.org/cen/80th/technetium.html)*. Chemical & Engineering News.* ***81*** *(36): 110.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/cen-v081n036.p110*](https://doi.org/10.1021%2Fcen-v081n036.p110)*.*

  Irregular crystals and trace impurities raise this transition temperature to 11.2 K for 99.9% pure technetium powder.([Schwochau 2000](https://en.wikipedia.org/wiki/Technetium#CITEREFSchwochau2000), p. 96)

  As of 2005, technetium-99 in the form of [ammonium pertechnetate](https://en.wikipedia.org/wiki/Ammonium_pertechnetate) is available to holders of an [Oak Ridge National Laboratory](https://en.wikipedia.org/wiki/Oak_Ridge_National_Laboratory) permit:*Hammond, C. R. (2004). "The Elements". Handbook of Chemistry and Physics (81st ed.). CRC press.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-8493-0485-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-8493-0485-9)*.*

* 1.  The [anaerobic](https://en.wikipedia.org/wiki/Anaerobic_organism), [spore](https://en.wikipedia.org/wiki/Endospore)-forming [bacteria](https://en.wikipedia.org/wiki/Bacteria) in the [*Clostridium*](https://en.wikipedia.org/wiki/Clostridium) [genus](https://en.wikipedia.org/wiki/Genus) are able to reduce Tc(VII) to Tc(IV). *Clostridia* bacteria play a role in reducing iron, [manganese](https://en.wikipedia.org/wiki/Manganese), and uranium, thereby affecting these elements' solubility in soil and sediments. Their ability to reduce technetium may determine a large part of mobility of technetium in industrial wastes and other subsurface environments. *Francis, A. J.; Dodge, C. J.; Meinken, G. E. (2002). "Biotransformation of pertechnetate by Clostridia". Radiochimica Acta.* ***90*** *(9–11): 791–797.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1524/ract.2002.90.9-11\_2002.791*](https://doi.org/10.1524%2Fract.2002.90.9-11_2002.791)*.*

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| * [**v**](https://en.wikipedia.org/wiki/Template:Technetium_compounds) * [**t**](https://en.wikipedia.org/wiki/Template_talk:Technetium_compounds) * [**e**](https://en.wikipedia.org/w/index.php?title=Template:Technetium_compounds&action=edit)   **Technetium compounds** | |

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* [Synthetic elements](https://en.wikipedia.org/wiki/Category:Synthetic_elements)
* [Radiobiology](https://en.wikipedia.org/wiki/Category:Radiobiology)
* [Chemical elements predicted by Dmitri Mendeleev](https://en.wikipedia.org/wiki/Category:Chemical_elements_predicted_by_Dmitri_Mendeleev)

**Navigation menu**

* Not logged in
* [Talk](https://en.wikipedia.org/wiki/Special:MyTalk)
* [Contributions](https://en.wikipedia.org/wiki/Special:MyContributions)
* [Create account](https://en.wikipedia.org/w/index.php?title=Special:CreateAccount&returnto=Technetium)
* [Log in](https://en.wikipedia.org/w/index.php?title=Special:UserLogin&returnto=Technetium)
* [Article](https://en.wikipedia.org/wiki/Technetium)
* [Talk](https://en.wikipedia.org/wiki/Talk:Technetium)
* [Read](https://en.wikipedia.org/wiki/Technetium)
* [Edit](https://en.wikipedia.org/w/index.php?title=Technetium&action=edit)
* [View history](https://en.wikipedia.org/w/index.php?title=Technetium&action=history)

**Search**

Top of Form

Bottom of Form

* [Main page](https://en.wikipedia.org/wiki/Main_Page)
* [Contents](https://en.wikipedia.org/wiki/Portal:Contents)
* [Featured content](https://en.wikipedia.org/wiki/Portal:Featured_content)
* [Current events](https://en.wikipedia.org/wiki/Portal:Current_events)
* [Random article](https://en.wikipedia.org/wiki/Special:Random)
* [Donate to Wikipedia](https://donate.wikimedia.org/wiki/Special:FundraiserRedirector?utm_source=donate&utm_medium=sidebar&utm_campaign=C13_en.wikipedia.org&uselang=en)
* [Wikipedia store](https://shop.wikimedia.org)

**Interaction**

* [Help](https://en.wikipedia.org/wiki/Help:Contents)
* [About Wikipedia](https://en.wikipedia.org/wiki/Wikipedia:About)
* [Community portal](https://en.wikipedia.org/wiki/Wikipedia:Community_portal)
* [Recent changes](https://en.wikipedia.org/wiki/Special:RecentChanges)
* [Contact page](https://en.wikipedia.org/wiki/Wikipedia:Contact_us)

**Tools**

* [What links here](https://en.wikipedia.org/wiki/Special:WhatLinksHere/Technetium)
* [Related changes](https://en.wikipedia.org/wiki/Special:RecentChangesLinked/Technetium)
* [Upload file](https://en.wikipedia.org/wiki/Wikipedia:File_Upload_Wizard)
* [Special pages](https://en.wikipedia.org/wiki/Special:SpecialPages)
* [Permanent link](https://en.wikipedia.org/w/index.php?title=Technetium&oldid=871571693)
* [Page information](https://en.wikipedia.org/w/index.php?title=Technetium&action=info)
* [Wikidata item](https://www.wikidata.org/wiki/Special:EntityPage/Q1054)
* [Cite this page](https://en.wikipedia.org/w/index.php?title=Special:CiteThisPage&page=Technetium&id=871571693)

**Print/export**

* [Create a book](https://en.wikipedia.org/w/index.php?title=Special:Book&bookcmd=book_creator&referer=Technetium)
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* [Español](https://es.wikipedia.org/wiki/Tecnecio)
* [Français](https://fr.wikipedia.org/wiki/Techn%C3%A9tium)
* [한국어](https://ko.wikipedia.org/wiki/%ED%85%8C%ED%81%AC%EB%84%A4%ED%8A%AC)
* [Italiano](https://it.wikipedia.org/wiki/Tecnezio)
* [Русский](https://ru.wikipedia.org/wiki/%D0%A2%D0%B5%D1%85%D0%BD%D0%B5%D1%86%D0%B8%D0%B9)
* [Tagalog](https://tl.wikipedia.org/wiki/Technetium)
* [Tiếng Việt](https://vi.wikipedia.org/wiki/Tecneti)
* [中文](https://zh.wikipedia.org/wiki/%E9%94%9D)

[Edit links](https://www.wikidata.org/wiki/Special:EntityPage/Q1054#sitelinks-wikipedia)

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