見本

'14

推　薦

医学部医学科小論文問題 2

注　意　事　項

1. 試験開始の合図があるまで問題冊子を開いてはいけません。
2. この問題冊子のページ数は15ページです。問題冊子、答案用紙（4枚）及び下書き用紙（3枚）に落丁、乱丁、印刷不鮮明などがある場合には申し出てください。
3. 解答は指定の答案用紙に記入してください。
   (1) 文字はわかりやすく、横書きで、はっきりと記入してください。
   (2) 解答の字数に制限がある場合には、それを守ってください。
   (3) 訂正、挿入の語句は余白に記入してください。
   (4) ローマ字、数字を使用するときは、ます目にとらわれなくてもかまいません。
4. 試験時間は90分です。
5. 答案用紙は持ち帰ってはいけません。
6. 問題冊子と下書き用紙は持ち帰ってください。

（余白）

次の文章はある講演を文章化したものである。これを読んで設問 A ～ F に答えなさい。なお、添字のある語句には脚注がある。

Donald Sadoway[1] "The Missing Link To Renewable Energy"

The electricity powering the lights in this theater was generated just moments ago. Because the way things stand today, electricity demand must be in constant balance with electricity supply. If in the time that it took me to walk out here on this stage, some tens of megawatts of wind power stopped pouring into the grid[2], the difference would have to be made up from other generators immediately. But coal plants, nuclear plants can't respond fast enough. A giant battery could. With a giant battery, we'd be able to address the problem of intermittency that prevents wind and solar from contributing to the grid in the same way that coal, gas and nuclear do today.

You see, the battery is the key enabling device here. With it, we could draw electricity from the sun even when the sun doesn't shine. **(A)** <u>And that changes everything</u>. Because then renewables such as wind and solar come out from the wings, here to center stage. Today I want to tell you about such a device. It's called the liquid metal battery. It's a new form of energy storage that I invented at MIT along with a team of my students and post-docs[3].

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1 Donald Robert Sadoway is the current (as of January 2013) John F. Elliott Professor of Materials Chemistry at the Massachusetts Institute of Technology (MIT). A faculty member in the Department of Materials Science Engineering, he is a noted expert on batteries and has done significant research on how to improve the performance and longevity of portable power sources. (from Wikipedia)

2 An electrical grid is an interconnected network for delivering electricity from suppliers to consumers.

3 Post-doc, or postdoctoral fellow, is a person engaged in postdoctoral research, which is undertaken after the completion of doctoral research.

Now the theme of this year's TED Conference[4] is Full Spectrum. The OED[5] defines spectrum as "The entire range of wavelengths of electromagnetic radiation, from the longest radio waves to the shortest gamma rays *of which the range of visible light is only a small part.*" So I'm not here today only to tell you how my team at MIT has drawn out of nature a solution to one of the world's great problems. I want to go full spectrum and tell you how, in the process of developing this new technology, we've uncovered some surprising heterodoxies[6] that can serve as lessons for innovation, ideas worth spreading. And you know, **(B)** if we're going to get this country out of its current energy situation, we can't just conserve our way out; we can't just drill our way out; we can't bomb our way out. We're going to do it the old-fashioned American way, we're going to invent our way out, working together.

(Applause)

Now let's get started. The battery was invented about 200 years ago by a professor, Alessandro Volta, at the University of Padua in Italy. His invention gave birth to a new field of science, electrochemistry, and new technologies such as electroplating[7]. Perhaps overlooked, Volta's invention of the battery for the first time also demonstrated the utility of a professor. (Laughter) Until Volta, nobody could imagine a professor could be of any use.

(C) Here's the first battery — a stack of coins, zinc and silver, separated by cardboard[8] soaked in brine (**Figure 1**). This is the starting point for designing a battery — two

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4 TED (Technology, Entertainment, Design) is a global set of conferences owned by the private non-profit Sapling Foundation, under the slogan "ideas worth spreading". (from Wikipedia)

5 Oxford English Dictionary.

6 Opinions or ideas contrary to or different from an established standard.

7 electroplate : coat (a metal object) by electrolytic deposition with chromium, silver, or another metal.

8 Cardboard is a generic term for a heavy-duty paper.

Figure 1. Alessandro Volta and his battery on 10000 Lire 1984 banknote from Italy.

electrodes, in this case metals of different composition, and an electrolyte, in this case salt dissolved in water. The science is that simple. Admittedly, I've left out a few details.

Now I've taught you that battery science is straightforward and the need for grid-level storage is compelling[9], but the fact is that today there is simply no battery technology capable of meeting the demanding performance requirements of the grid — namely uncommonly high power, long service lifetime and super-low cost. We need to think about the problem differently. We need to think big, we need to think cheap.

So let's abandon the paradigm[10] of let's search for the coolest chemistry and then hopefully we'll chase down the cost curve by just making lots and lots of product. Instead,

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[9] compelling : evoking interest, attention, or admiration in a powerfully irresistible way.

[10] A philosophical or theoretical framework of any kind.

let's invent to the price point of the electricity market. So that means that certain parts of the periodic table are axiomatically[11] off-limits. This battery needs to be made out of earth-abundant elements. I say, if you want to make something dirt cheap, make it out of dirt — (Laughter) preferably dirt that's locally sourced. And we need to be able to build this thing using simple manufacturing techniques and factories that don't cost us a fortune.

So about six years ago, I started thinking about this problem. And in order to adopt a fresh perspective, I sought inspiration from beyond the field of electricity storage. In fact, I looked to a technology that neither stores nor generates electricity, but instead consumes electricity, huge amounts of it. I'm talking about the production of aluminum. The process was invented in 1886 by a couple of 22-year-olds — Hall[12] in the United States and Héroult[13] in France. And just a few short years following their discovery, aluminum changed from a precious metal costing as much as silver to a common structural material.

You're looking at the cell house of a modern aluminum smelter[14] (**Figure 2**). It's about 50 feet wide and recedes about half a mile — row after row of cells that, inside, resemble Volta's battery, with **(D)** <u>three important differences</u>. Volta's battery works at room temperature. It's fitted with solid electrodes and an electrolyte that's a solution of salt and water. The Hall-Héroult cell operates at high temperature, a temperature high enough that the aluminum metal product is liquid. The electrolyte is not a solution of salt and water, but rather salt that's melted. It's this combination of liquid metal, molten salt and high temperature that allows us to send high current through this thing. Today, we can produce

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[11] axiomatic : self-evident or unquestionable.

[12] Charles Martin Hall (December 6, 1863 – December 27, 1914) was an American inventor, music enthusiast, and chemist. He is best known for his invention in 1886 of an inexpensive method for producing aluminium, which became the first metal to attain widespread use since the prehistoric discovery of iron. (from Wikipedia)

[13] Paul (Louis-Toussaint) Héroult (April 10, 1863 – May 9, 1914) was a French scientist. He was the inventor of the aluminium electrolysis and of the electric steel furnace. (from Wikipedia)

[14] smelt : extract (metal) from its ore[15] by a process involving heating and melting.

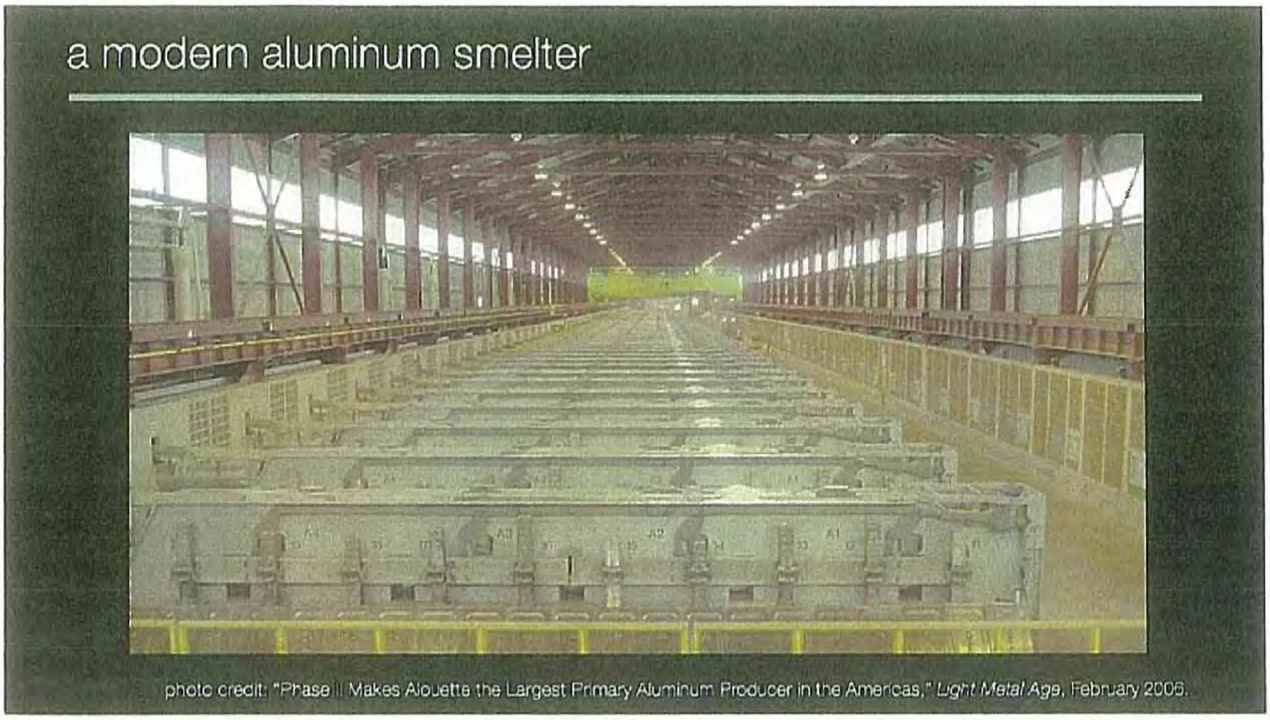

Figure 2. A modern aluminum smelter.

virgin metal from ore[15] at a cost of less than 50 cents a pound. That's the economic miracle of modern electrometallurgy[16].

It is this that caught and held my attention to the point that I became obsessed with inventing a battery that could capture this gigantic economy of scale. And I did. I made the battery all liquid — liquid metals for both electrodes and a molten salt for the electrolyte. I'll show you how. So I put low-density liquid metal at the top, put a high-density liquid metal at the bottom, and molten salt in between.

[15] An ore is a naturally occurring solid material from which a metal or valuable mineral can be extracted profitably.

[16] Electrometallurgy is the science of producing metals from metallic ores through the use of electricity.

So now, how to choose the metals? For me, the design exercise always begins here with the periodic table, enunciated[17] by another professor, Dmitri Mendeleyev[18] (**Figure 3**). Everything we know is made of some combination of what you see depicted here. And that includes our own bodies. I recall the very moment one day when I was searching for a pair of metals that would meet the constraints of earth abundance, different, opposite density and high mutual reactivity. I felt the thrill of realization when I knew I'd come upon the answer. Magnesium for the top layer. And antimony for the bottom layer. You know, I've got to tell you, one of the greatest benefits of being a professor: colored chalk.

(Laughter)

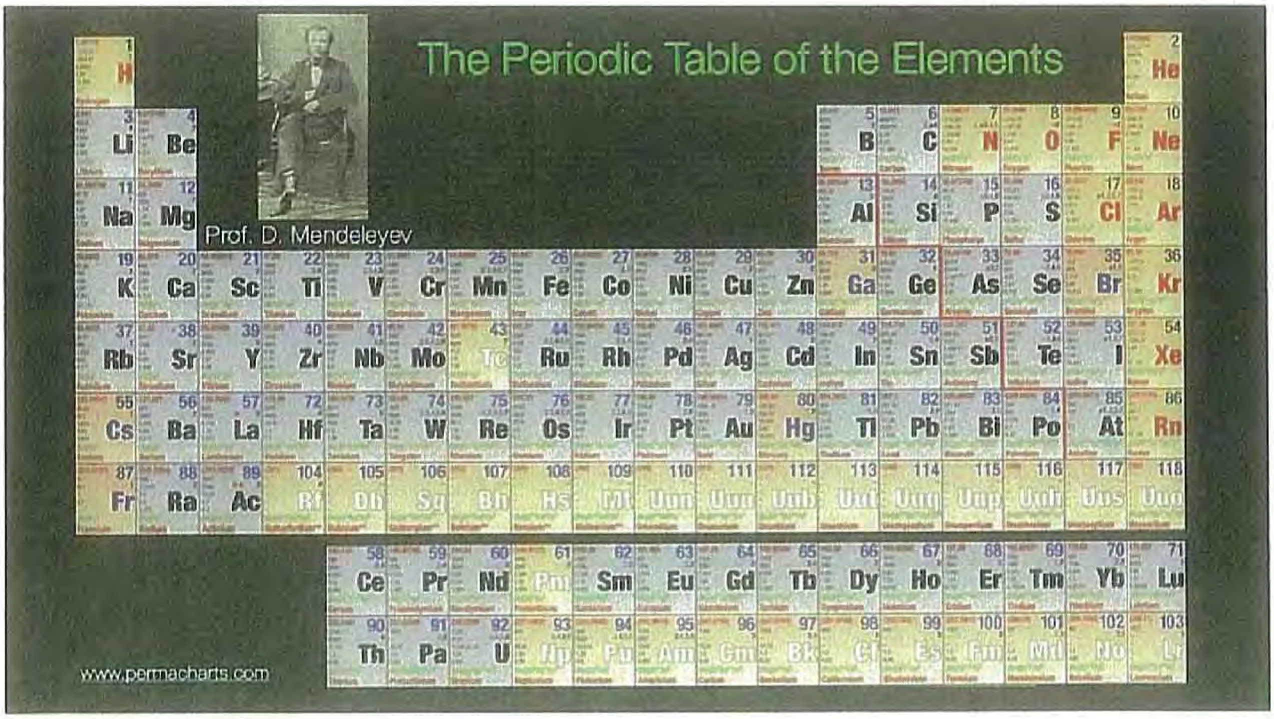

Figure 3. The periodic table of the elements.

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[17] enunciate : say or pronounce clearly.

[18] Dmitri Ivanovich Mendeleev (8 February 1834 – 2 February 1907) was a Russian chemist and inventor. He formulated the Periodic Law, created his own version of the periodic table of elements, and used it to correct the properties of some already discovered elements and also to predict the properties of elements yet to be discovered. (from Wikipedia)

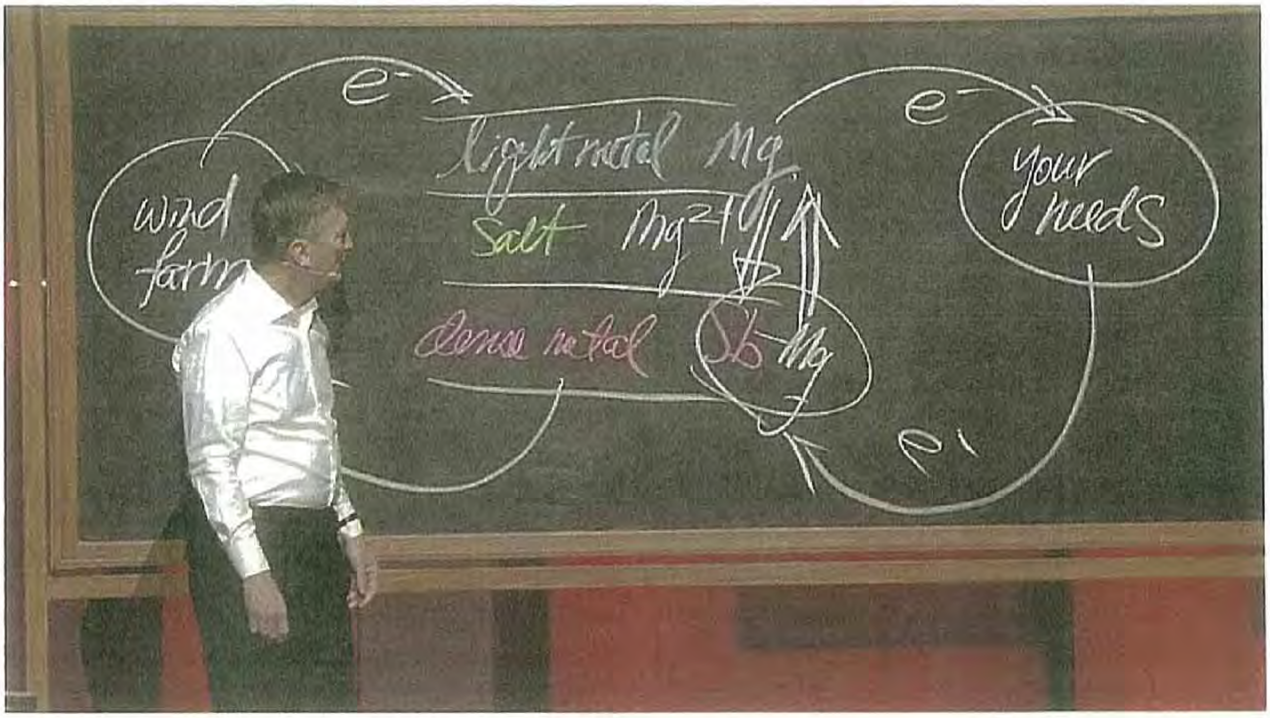

Figure 4. The principle of the liquid metal battery.

So to produce current, magnesium loses two electrons to become magnesium ion, which then migrates across the electrolyte, accepts two electrons from the antimony, and then mixes with it to form an alloy[19]. The electrons go to work in the real world out here, powering our devices. Now **(E)** to charge the battery, we connect a source of electricity. It could be something like a wind farm. And then we reverse the current. And this forces magnesium to de-alloy and return to the upper electrode, restoring the initial constitution of the battery. And the current passing between the electrodes generates enough heat to keep it at temperature (**Figure 4**).

It's pretty cool, at least in theory. But does it really work? So what to do next? We go to the laboratory. Now do I hire seasoned[20] professionals? No, I hire a student and mentor[21] him,

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[19] An alloy is a metal made by combining two or more metallic elements.

[20] seasoned : accustomed to particular conditions; experienced.

[21] mentor : advise or train (someone, especially a younger colleague).

teach him how to think about the problem, to see it from my perspective and then turn him loose. This is that student, David Bradwell, who, in this image, appears to be wondering if this thing will ever work (**Figure 5**). What I didn't tell David at the time was I myself wasn't convinced it would work.

But David's young and he's smart and he wants a Ph.D.[22], and he proceeds to build — (Laughter) He proceeds to build the first ever liquid metal battery of this chemistry. And based on David's initial promising results, which were paid with seed funds at MIT, I was able to attract major research funding from the private sector and the federal government.

Figure 5. Donald Sadoway and his student David Bradwell watching their battery.

[22] Ph.D., or Doctor of Philosophy, is postgraduate academic degree awarded by universities. In the U.S. many universities require coursework in addition to research for Ph.D. degrees, which in average take 7 years of hard work.

And that allowed me to expand my group to 20 people, a mix of graduate students[23], post-docs and even some undergraduates[24].

And I was able to attract really, really good people, people who share my passion for science and service to society, not science and service for career building. And if you ask these people why they work on liquid metal battery, their answer would hearken back to[25] President Kennedy's remarks at Rice University[26] in 1962 when he said — and I'm taking liberties here — "We choose to work on grid-level storage, not because it is easy, but because it is hard."

(Applause)

So this is the evolution of the liquid metal battery. We start here with our workhorse one watt-hour cell. I called it the shot glass. We've operated over 400 of these, perfecting their performance with a plurality of chemistries — not just magnesium and antimony. Along the way we scaled up to the 20 watt-hour cell. I call it the hockey puck. And we got the same remarkable results. And then it was onto the saucer. That's 200 watt-hours. The technology was proving itself to be robust[27] and scalable[28]. But the pace wasn't fast enough for us. So a year and a half ago, David and I, along with another research staff-member, formed a company to accelerate the rate of progress and the race to manufacture product.

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[23] A graduate student is a student engaged in a doctoral program.

[24] An undergraduate is a student at a college or university who has not yet earned a bachelor's or equivalent degree.

[25] hearken back to : mention or remember (something from the past).

[26] William Marsh Rice University, commonly referred to as Rice University or Rice, is a private research university located in Houston, Texas, United States.

[27] robust : able to withstand or overcome adverse conditions.

[28] scalable : able to be changed in size or scale.

So today at LMBC[29], we're building cells 16 inches in diameter with a capacity of one kilowatt-hour — 1,000 times the capacity of that initial shot glass cell. We call that the pizza. And then we've got a four kilowatt-hour cell on the horizon. It's going to be 36 inches in diameter. We call that the bistro table, but it's not ready yet for prime-time[30] viewing. And one variant of the technology has us stacking these bistro tabletops into modules, aggregating the modules into a giant battery that fits in a 40-foot shipping container for placement in the field. And this has a nameplate capacity of two megawatt-hours — two million watt-hours. That's enough energy to meet the daily electrical needs of 200 American households[31]. So here you have it, grid-level storage: silent, emissions-free, no moving parts, remotely controlled, designed to the market price point without subsidy[32].

So what have we learned from all this? (Applause) So what have we learned from all this? Let me share with you some of the surprises, the **(F)** heterodoxies. They lie beyond the visible. Temperature: Conventional wisdom says set it low, at or near room temperature, and then install a control system to keep it there. Avoid thermal runaway[33]. Liquid metal battery is designed to operate at elevated temperature with minimum regulation. Our battery can handle the very high temperature rises that come from current surges[34]. Scaling: Conventional wisdom says reduce cost by producing many. Liquid metal battery is designed to reduce cost by producing fewer, but they'll be larger. And finally, human resources: Conventional wisdom says hire battery experts, seasoned professionals, who

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[29] Liquid Metal Battery Corporation.

[30] Prime time is the time at which a radio or television audience is expected to be at its highest.

[31] A household is a house and its occupants regarded as a unit.

[32] A subsidy is a sum of money granted by the state or a public body to help an industry or business keep the price of a commodity or service low.

[33] Thermal runaway refers to a situation where an increase in temperature changes the conditions in a way that causes a further increase in temperature, often leading to a destructive result.

[34] A surge is a sudden powerful forward or upward movement.

can draw upon their vast experience and knowledge. To develop liquid metal battery, I hired students and post-docs and mentored them. In a battery, I strive to maximize electrical potential; when mentoring, I strive to maximize human potential. So you see, the liquid metal battery story is more than an account of inventing technology, it's a blueprint for inventing inventors, full-spectrum.

(Applause)

出典： TED 2012（http://www.ted.com/talks/donald_sadoway_the_missing_link_to_renewable_energy.html）

A. 下線部について、現在の問題がどういうものか、それがどう解決されるのか。本文を参考にして、答案用紙 2-1 のA欄に具体的に句読点を含めて日本語180字以内で説明しなさい。

B. 下線部について講演者の意図がわかるように和訳しなさい。答案用紙 2-1 のB欄に句読点を含めて最大200字の範囲内で記入しなさい。

C. この電池の負極と正極で起こる化学反応をそれぞれ化学式で表し、答案用紙 2-2 のCの各欄に記入しなさい。

D. 下線部についてどう異なるか。この講演の内容に即して、答案用紙 2-2 のDの比較表の空欄（9か所）に当てはまる語句を日本語で記入しなさい。

E. 下線部の反応について、つぎの2つの問に答えなさい。

(1) 負極と正極に分けて化学式で表し、答案用紙 2-3 のE(1)の各欄に記入しなさい。ただし、この場合の負極・正極とは放電時の負極・正極をいう。

(2) この電池の試作品「the shot glass」を使い、一旦放電させてから充電の試験をした。電池と電源を直列に接続し、200 mA の電流を 3600 秒間流した。電流が損失なくすべて電池の反応に使われたと仮定すると、このとき負極の金属の増減は何 mg になるか。答案用紙 2-3 のE(2)欄に記入しなさい。ただし、答えだけでなく途中の計算過程の説明と計算式も書くこと。なお、ファラデー定数を 9.65×10^4 C/mol とする。この講演で言及のあった元素の原子量を下表に示す。

元素	Na	Mg	Al	Cl	Zn	Ag	Sb
原子量	23.0	24.3	27.0	35.5	65.4	108	122

F. 下線部の言葉が講演中でしばしば使われていた（脚注6参照）。この講演では具体的に何を差しているか。答案用紙 2-4 のF欄に句読点を含めて日本語160字以内で説明しなさい。

(余白)