

'13

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9ページです。問題冊子、答案用紙（3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、数式を使用するときは、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。

訂正

P8.設問 A 2行目

～解答用紙 2-1 の A 欄に計算過程と答え（有効数字 3 桁で単位を含む）を記入しなさい。

P8.設問 F 2行目

～解答用紙 2-3 の F 欄に計算過程と答え（有効数字 2 桁で単位も含む）を記入しなさい。

P9.設問 G 8行目

～解答用紙 2-3 の G 欄に計算過程と答え（有効数字 2 桁）を記入しなさい。

次の文章を読んで、設問 A~G に答えなさい。星印 (*) のついた単語には、文末に訳注があります。

PHYSICOCHEMICAL* PROPERTIES OF ELECTROLYTE* SOLUTIONS

Molarity* and Equivalence*

The amount of a substance dissolved in a solution (i.e., its concentration) is expressed in terms of either molarity or equivalence. Molarity is the amount of a substance relative to its molecular weight. For example, glucose* has a molecular weight of 180 g/mole. If 1 L of water contains 1 g of glucose, the molarity of this glucose solution would be determined as:

$$\frac{1 \text{ g/L}}{180 \text{ g/mole}} = 0.0056 \text{ moles/L or } 5.6 \text{ mmol/L} \quad (1-1)$$

For uncharged molecules, such as glucose and urea*, concentrations in the body fluids are usually expressed in terms of molarity. Because many of the substances of biologic interest are present at very low concentrations, units are more frequently expressed in the millimolar range (mmol/L or mM).

The concentration of solutes*, which normally dissociate into more than one particle when dissolved in solution (e.g., NaCl), is usually expressed in terms of equivalence. Equivalence refers to the stoichiometry* of the interaction between cation* and anion* and is determined by the valence* of these ions. (A) For example, consider a 1-L solution containing 9 g of NaCl (molecular weight = 58.4 g/mole). The molarity of this solution is 154 mmol/L. Because NaCl dissociates* into Na⁺ and Cl⁻ ions, and assuming complete dissociation, this solution contains 154 mmol/L of Na⁺ and 154 mmol/L of Cl⁻. Because the valence of these ions is 1, these concentrations can also be expressed as milliequivalents* (mEq) of the ion per liter (i.e., 154 mEq/L for Na⁺ and Cl⁻, respectively).

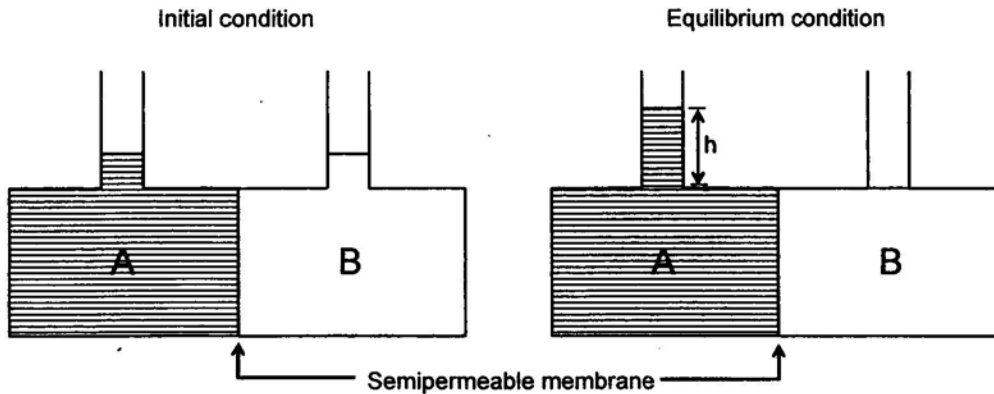
For univalent* ions, such as Na⁺ and Cl⁻, concentrations expressed in terms of molarity and equivalence are identical. However, this is not true for ions having valences greater than 1. Accordingly, the concentration of Ca⁺⁺ (molecular weight = 40.1 g/mole and valence = 2) in a 1-L solution containing 0.1 g of this ion could be expressed as:

$$\begin{aligned} \frac{0.1 \text{ g/L}}{40.1 \text{ g/mole}} &= 2.5 \text{ mmol/L} \\ &= 2.5 \text{ mmol/L} \times 2 \text{ Eq/mole} = 5 \text{ mEq/L} \end{aligned} \quad (1-2)$$

Although some exceptions exist, it is customary to express concentrations of ions in milliequivalents per liter.

Osmosis* and Osmotic Pressure

The movement of water across cell membranes* occurs by the process of osmosis. The driving force for this movement is the osmotic pressure difference across the cell membrane. Figure 1 illustrates the concept of osmosis and the measurement of the osmotic pressure of a solution.



(B) **Figure 1** Schematic representation of osmotic water movement and the generation of an osmotic pressure. Compartment A and compartment B are separated by a semipermeable* membrane (i.e., the membrane is highly permeable to water but impermeable to solute). Compartment A contains a solute, and compartment B contains only distilled water*. Over time, water moves by osmosis from compartment B to compartment A. (Note: This water movement is driven by the concentration gradient* for water. Because of the presence of solute particles in compartment A, the concentration of water in compartment A is less than that in compartment B. Consequently, water moves across the semipermeable membrane from compartment B to compartment A down its gradient). This raises the level of fluid in compartment A and decreases the level in compartment B. At equilibrium*, the hydrostatic pressure* exerted by the column of water (h) stops the movement of water from compartment B to A. This pressure is equal and opposite to the osmotic pressure exerted by the solute particles in compartment A.

Osmotic pressure is determined solely by the number of solute particles in the solution. It is not dependent upon such factors as the size of the solute particles, their mass*, or chemical nature (e.g., valence). Osmotic pressure (π), measured in atmospheres* (atm*), is calculated by van't Hoff's law* as:

$$\pi (\text{atm}) = nCRT \quad (1-3)$$

where:

n = Number of dissociable particles per molecule

C = Total solute concentration

R = Gas constant

T = Temperature in degrees Kelvin* ($^{\circ}\text{K}$)

For a molecule that does not dissociate in water, such as glucose or urea, a solution containing 1 mmol/L of these solutes at 37°C can exert an osmotic pressure of 2.54×10^{-2} atm as calculated by equation* 1-3 using the following values:

$$n = 1$$

$$C = 0.001 \text{ mol/L}$$

$$R = 0.082 \text{ atm L/mol}^\circ\text{K}$$

$$T = 310 \text{ }^\circ\text{K}$$

Because 1 atmosphere equals 760 mm Hg* at sea level, π for this solution can also be expressed as 19.3 mmHg. Alternatively, osmotic pressure is expressed in terms of osmolarity* (see the following). Thus, a solution containing 1 mmol/L of solute particles exerts an osmotic pressure of 1 milliosmole/L (1 mOsm/L).

For substances that dissociate in a solution, n of equation 1-3 has a value other than 1. For example, a 150 mmol/L solution of NaCl has an osmolarity of 300 mOsm/L because each molecule of NaCl dissociates into a Na^+ and a Cl^- ion (i.e., $n = 2$). (c) If dissociation of a substance into its component ions is not complete, n is not an (_____). Accordingly, osmolarity for any solution can be calculated as:

$$\text{Osmolarity} = \text{concentration} \times \text{number of dissociable particles} \quad (1-4)$$

$$\text{mOsm/L} = \text{mmol/L} \times \# \text{ particles/mole (\#: number)}$$

Osmolarity and Osmolality*

Osmolarity and osmolality are frequently confused and incorrectly interchanged. Osmolarity refers to the number of solute particles per 1 L of solvent*, whereas osmolality is the number of solute particles in 1 kg of solvent. For dilute solutions, the difference between osmolarity and osmolality is insignificant. Measurements of osmolarity are temperature dependent because the volume of solvent varies with temperature (i.e., the volume is larger at higher temperatures). In contrast, osmolality, which is based on the mass of the solvent, is temperature independent. For this reason, osmolality is the preferred term for biologic systems and is used throughout this and subsequent chapters. Osmolality has the units of Osm/kg H_2O . Because of the dilute nature of physiologic* solutions and because water is the solvent, osmolalities are expressed as milliosmoles per kilogram water (mOsm/kg H_2O).

Tonicity*

The tonicity of a solution is related to its effect on the volume of a cell. Solutions that do not change the volume of a cell are said to be isotonic*. A hypotonic* solution causes a cell to swell, and a hypertonic* solution causes a cell to shrink. Although related to osmolality, tonicity also takes into consideration the ability of the solute to cross the cell membrane.

Consider two solutions: a 300 mmol/L solution of sucrose* and a 300 mmol/L solution of urea. Both solutions have an osmolality of 300 mOsm/kg H₂O and therefore are said to be isosmotic (i.e., they have the same osmolality). (D) When red blood cells*, which for the purpose of this illustration also have an intracellular* fluid osmolality of 300 mOsm/kg H₂O, are placed in the two solutions, those in the sucrose solution maintain their normal volume but those placed in urea swell and eventually burst. Thus, the sucrose solution is isotonic and the urea solution is hypotonic. The differential effect of these solutions on red cell volume is related to the permeability* of the plasma membrane* to sucrose and urea. The red cell membrane contains uniporters* for urea. Thus, urea easily crosses the cell membrane (i.e., the membrane is permeable to urea), driven by concentration gradient (i.e., extracellular* [urea]* > intracellular [urea]). In contrast, the red cell membrane does not contain sucrose transporters*, and sucrose cannot enter the cell (i.e., the membrane is impermeable to sucrose).

To exert an osmotic pressure across a membrane, a solute must not permeate* that membrane. Because the red cell membrane is impermeable to sucrose, it exerts an osmotic pressure equal and opposite to the osmotic pressure generated by the contents of the red cell (in this case 300 mOsm/kg H₂O). In contrast, urea is readily able to cross the red blood cell membrane, and it cannot exert an osmotic pressure to balance that generated by the intracellular solutes of the red blood cell. Consequently, sucrose is termed an effective osmole and urea is an ineffective osmole.

To take into account the effect of a solute's membrane permeability on osmotic pressure, it is necessary to rewrite equation 1-3 as:

$$\pi_{\text{eff}}^* (\text{atm}) = \sigma(nCRT) \quad (1-5)$$

where σ is the reflection coefficient* or osmotic coefficient and is a measure of the relative ability of the solute to cross a cell membrane.

(E) For a solute that can freely cross the cell membrane, such as urea in this example, $\sigma = 0$, and no effective osmotic pressure* is exerted. Thus, urea is an ineffective osmole for red blood cells. In contrast, $\sigma = 1$ for a solute that cannot cross the cell membrane (i.e., sucrose). Such a substance is said to be an effective osmole. Many solutes are neither completely able nor completely unable to cross cell membranes (i.e., $0 < \sigma < 1$) and generate an osmotic pressure that is only a fraction of what is expected from the total solute concentration.

(Bruce M. Koeppen, Bruce A. Stanton., Physicochemical properties of electrolyte solutions. Renal Physiology, 2007 より、一部改変)

Reprinted from "Renal Physiology", Koeppen, Bruce M. and Bruce A. Stanton, Chapter 1: Physiology of Body Fluids, copyright © 2013, with permission from Elsevier.

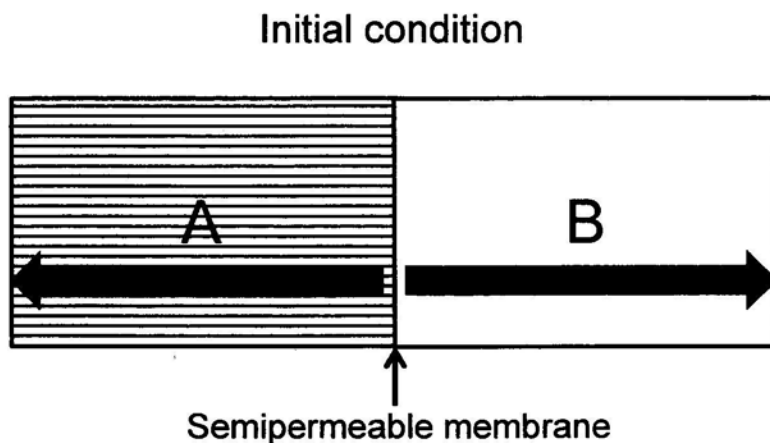
*訳注

| | |
|----------------------|--|
| physicochemical | 物理化学的 |
| electrolyte | 電解質 |
| molarity | モル濃度 |
| equivalence | 等量 |
| glucose | グルコース (ブドウ糖) |
| urea | 尿素 |
| solutes | 溶質 |
| stoichiometry | 化学量論 |
| cation | 陽イオン |
| anion | 陰イオン |
| valence | 原子価 |
| dissociates | 解離する、分離する |
| milliequivalents | ミリ等量 |
| univalent | 一価の |
| osmosis | 浸透 |
| membranes | 膜 |
| semipermeable | 半透性の |
| distilled water | 蒸留水 |
| gradient | 勾配、傾斜 |
| equilibrium | 平衡 |
| hydrostatic pressure | 静水圧 |
| mass | 質量 |
| atmospheres | 気圧 |
| atm | 気圧の単位 |
| van't Hoff's law | ファントホッフの法則 |
| degree Kelvin | ケルビン度 (絶対温度)、セルシウス温度 (°C) を t(°C) で絶対温度を T(°K)で表すと $T(^{\circ}K) = t(^{\circ}C) + 273.15$ という関係が成り立つ |
| equation | 式 |
| mm Hg | 圧力の単位 (1 mm Hg は 0.001316 気圧と等しい) |
| osmolarity | 容量オスモル濃度 |
| osmolality | 重量オスモル濃度 |
| solvent | 溶媒 |
| physiologic | 生理 (学) 的な |
| tonicity | 浸透圧、緊張度 |
| isotonic | 等張の |
| hypotonic | 低張の |
| hypertonic | 高張の |
| sucrose | スクロース (ショ糖) |
| red blood cells | 赤血球 |
| intracellular | 細胞内の |
| permeability | 透過性 |
| plasma membrane | 細胞膜 |
| uniporters | 単輸送体 |

| | |
|----------------------------|--------------|
| extracellular [urea] | 細胞外の 尿素濃度 |
| transporters | トランスポーター、輸送体 |
| permeate | 浸透する |
| π_{eff} | 有効浸透圧 |
| coefficient | 係数 |
| effective osmotic pressure | 有効浸透圧 |

設問

- A. 下線部 (A)の NaCl 溶液と同じ osmolarity の glucose 溶液を 1 L つくりたい。Glucose の必要量はいくらか。解答用紙 2-1 の A 欄に有効数字 3 桁で単位も含めて記入しなさい。
- B. 下線部 (B)の Figure 1 では compartment A と compartment B を隔てている半透膜はその境界で固定されている。いま下図のように、Initial condition において、半透膜を固定せず compartment の両端まで左右に可動 (移動: \leftrightarrow) できるように A と B の境界に設置する。この条件で Equilibrium condition における液体の変動や半透膜の位置はどうなるか。解答用紙 2-1 の B 欄に日本語 120 字以内 (句読点も含めて) で説明しなさい。ただし、compartment A と compartment B の成分および半透膜の透過性は Figure 1 と同じとする。



- C. 下線部 (C)の () 内に入る単語を解答用紙 2-1 の C 欄に日本語で記入しなさい。
- D. 下線部 (D)について、この red blood cells を質量パーセント濃度 3% の NaCl 溶液に入れると red blood cells はどうなると予想されるか。予想の根拠を含めて解答用紙 2-2 の D 欄に日本語 120 字以内 (句読点も含めて) で記入しなさい。ただし、red blood cells の NaCl に対する reflection coefficient (σ) は 1 とする。
- E. 下線部 (E)について、urea 溶液と sucrose 溶液の有効浸透圧の差を求め、どちらがより高張であるかについて解答用紙 2-2 の E 欄にその根拠となる数値を示して、日本語で記入しなさい。両溶液とも 1 mOsm/L の osmolarity で 37.0°C の条件下にある。
- F. 塩化マグネシウム (MgCl_2) 1.20 g を水に溶かして 250 mL にした。この溶液の 25.0°C における有効浸透圧 π_{eff} を求めなさい。解答用紙 2-3 の F 欄に日本語で有効数字 2 桁で単位も含めて記入しなさい。ただし、 MgCl_2 はこの溶液中では完全に解離している。また、Mg の原子量: 24.3、Cl の原子量: 35.5、reflection coefficient (σ): 0.40 とする。

- G. 膜を介する浸透圧による水の流れ（水流）は、有効浸透圧 π_{eff} の差 $\Delta\pi_{\text{eff}}$ と膜の透過性によって生じる。この水流は次の式で求められる。

$$\text{水流} = \text{有効浸透圧の差} \Delta\pi_{\text{eff}} \times \text{膜の透過係数 } K_f$$

マンニトール (mannitol, $\text{C}_6\text{H}_{14}\text{O}_6$) は細胞膜非透過性の糖アルコールの一種である。10 mmol/L と 1.0 mmol/L の2つのマンニトール溶液の間を半透膜で区切った。半透膜の透過係数 K_f は 0.50 mL/min · atm であり、膜を通る水流は 0.10 mL/min であった。このとき、マンニトール溶液の 37.0°C における reflection coefficient (σ) を求めなさい。解答用紙 2-3 の G 欄に有効数字2桁で記入しなさい。