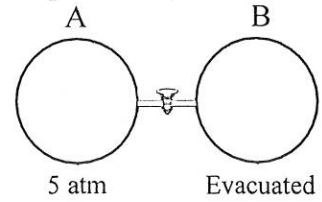
國立清華大學 114 學年度學士後醫學系單獨招生試題

考試科目(科目代碼)：化學與物理 (0103)

Choose one best answer for the following questions

【單選題】每題 2.5 分，共計 150 分，答錯一題倒扣 0.625 分，未作答，不給分亦不扣分。1~30 題為化學，31~60 題為物理。

1. Consider a system consisting of the following apparatus, in which gas is confined in flask A and there is a vacuum in flask B. The flasks are separated by a valve. Assuming that the flasks are perfectly insulated and will not allow the flow of heat into or out of the flasks to the surroundings. When the valve is opened, gas flows from flask A to flask B. Which of the following statements regarding this process is correct?



(A) No work is performed during the expansion of the gas.
(B) The gas expansion is a nonspontaneous process.
(C) The driving force for this process is enthalpy change.
(D) The internal energy change (ΔE) for this expansion process is > 0.
(E) The entropy change of the surrounding (ΔS_{surr}) for this process is > 0.

2. Given the K_{sp} values for the following compounds:

$PbCrO_4$: 2.0×10^{-16}　　$Zn(OH)_2$: 4.5×10^{-17}
$Pb(OH)_2$: 1.2×10^{-15}　　MnS: 2.3×10^{-13}

Which of the following statements about these compounds is *incorrect*?
(A) The solubility of MnS in water is pH dependent.
(B) $Zn(OH)_2$ has the lowest molar solubility in water.
(C) $Pb(OH)_2$ has the highest molar solubility in water.
(D) $Zn(OH)_2$ is more soluble upon decreasing the pH of solution.
(E) A saturated $PbCrO_4$ solution has a lower $[Pb^{2+}]$ than a saturated $Pb(OH)_2$ solution.

3. An unknown compound X was found to have molecular peak of m/z = 74 by mass spectrometry and a measured boiling point of 57°C at 1atm. Which of the following is most likely to be compound X?
(A) diethyl ether　　(B) methyl acetate　　(C) propionic acid
(D) butanone　　(E) *n*-pentane

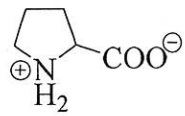
4. Consider the reaction: $a\ X(g) \rightleftharpoons b\ Y(g)$

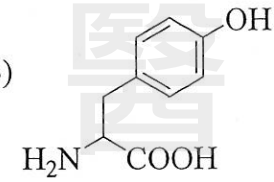
Each entry in the table below represents the equilibrium partial pressures of X and Y under different initial conditions at the same temperature. The coefficients a and b are the simplest integers. When the equilibrium partial pressure of X is 0.20 atm, the equilibrium partial pressure of Y is n atm. Which of the following statements is true?

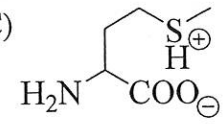
P_X (atm)	2.0	1.4	1.0	0.78	0.50	0.20
P_Y (atm)	4.0	2.0	1.0	0.60	0.25	n

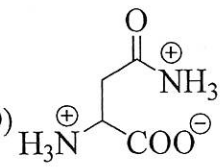
(A) $a = 1$　(B) $b = 2$　(C) $n = 0.10$　(D) $a = 2b$　(E) $a + b = 4$

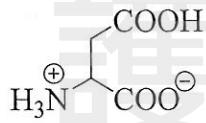
5. Which of the following amino acids has the correct ionized form for the functional groups at physiological pH (7.4)?

(A) 

(B) 

(C) 

(D) 

(E) 

6. Which of the following statements about electrochemical cells is *incorrect*?

(A) The standard potential ($E°$) in a concentration cell is zero.

(B) In a concentration cell, the higher ion concentration solution is present at the cathode.

(C) At equilibrium, the standard potential ($E°$) in a cell is zero.

(D) The cell potential (E) can determine the spontaneity of a cell.

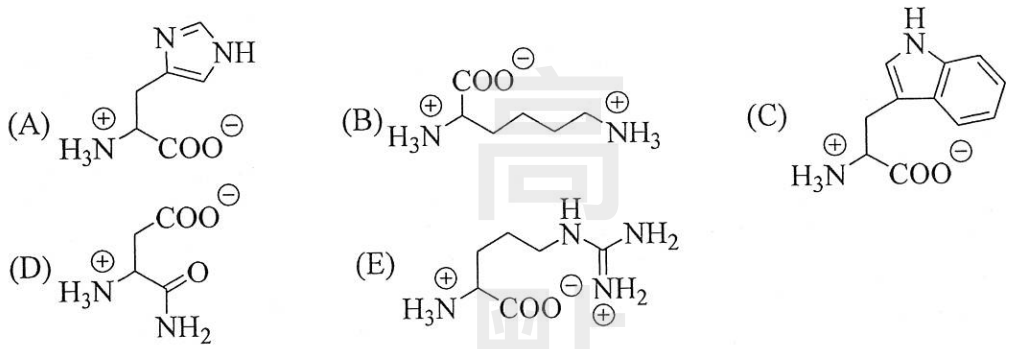
(E) In a concentration cell, decreasing the anode ion concentration will give rise to larger cell potentials.

7. Which of the following names for compounds complies to IUPAC nomenclature?

(A) 2,5-pentadiene　(B) *cis*-1-butene　(C) (*R*)-bromocyclopentane

(D) *trans*-1,1-dichlorocyclohexane　(E) propanal

8. Which of the following molecules does not belong to 20 common amino acids?



9. In preparation for the combustion demonstration, the assistant instructor injected equal molar amount of H_2 and O_2 into the balloon, but the demonstration had to be postponed until the next day due to safety setup problems. During the night, both gases leaked through the pores of the balloon. What is the molar ratio of O_2 to H_2 in the balloon the next day if 30% of the H_2 is leaking?

(A) 0.76　　(B) 0.95　　(C) 1.14　　(D) 1.32　　(E) 1.60

10. The following statements describe the chemical and physical properties of some representative elements and their compounds. Which statement is *incorrect*?

(A) Diborane (B_2H_6) has two three-center two-electron B–H–B bonds.

(B) Lithium metal is converted to lithium superoxide in the presence of excess molecular oxygen.

(C) Al_2O_3 is amphoteric and can dissolve in both acidic and basic solutions.

(D) The hydration of F^- decreases the entropy when HF dissociates in water, which contributes to make HF a weaker acid than HCl and HBr.

(E) SiC is an extremely hard substance because it has a covalent network structure similar to diamond.

11. Which of the available number of stereoisomers for the following open-chain monosaccharide is correct?

(A) aldopentose: 8 stereoisomers

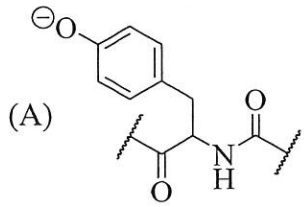
(B) aldohexose: 32 stereoisomers

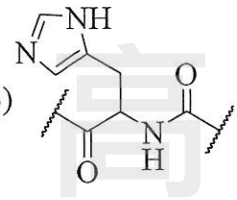
(C) ketotetrose: 4 stereoisomers

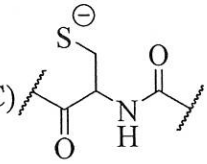
(D) aldotriose: 4 stereoisomers

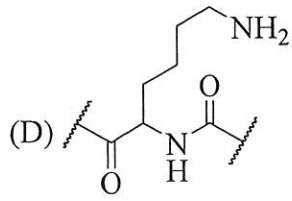
(E) ketohexose: 16 stereoisomers

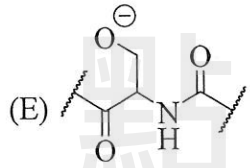
12. Which of the following forms of peptide residues is the most basic?

(A) 

(B) 

(C) 

(D) 

(E) 

13. Which of the following statements about nuclear reaction and stability is correct? (Z is the atomic number.)

(A) As Z increases, nuclides need a smaller neutron-to-proton ratio for stability.

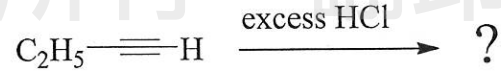
(B) Nuclides with small Z values are often observed to be α-particle producers.

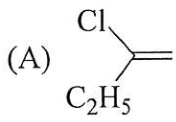
(C) A radioactive nuclide that decays from 2.00×10^{10} atoms to 2.50×10^{9} atoms in 30.0 min has a half-life of 15.0 min.

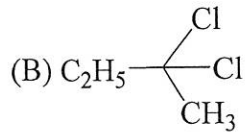
(D) Both the radioactive processes of positron production and electron capture increase the neutron-to-proton ratio.

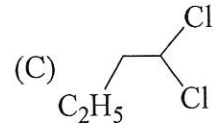
(E) If less than one neutron from each fission event causes another fission event, the fission situation is described as supercritical.

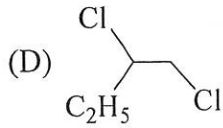
14. What is the major product for following reaction?

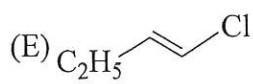


(A) 

(B) 

(C) 

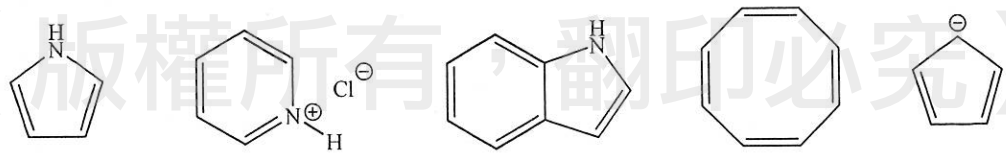
(D) 

(E) 

15. A mineral crystallizes in a cubic closest-packed array of oxygen ions (O^{2-}) with aluminum ions (Al^{3+}) in some of the octahedral holes and magnesium ions (Mg^{2+}) in some of the tetrahedral holes. Which of the following statements about this compound is correct?
(A) The empirical formula is $Al_2Mg_2O_5$.
(B) Half of the octahedral holes are filled with aluminum ions.
(C) One-fourth of the tetrahedral holes are filled with magnesium ions.
(D) There are two oxygen ions in a unit cell.
(E) There are four aluminum ions in a unit cell.

16. Two moles of a monatomic ideal gas were heated at a constant pressure of 1 atm from 200 K to 300 K. The entropy ($S°$) for this gas at 200 K is 6.00 J mol^{-1} K^{-1}. Regarding the related thermodynamic parameters during the process, which of the following statements is correct? (R = 8.31 J mol^{-1} K^{-1}; ln2 = 0.69; ln3 = 1.10)
(A) internal energy change (ΔE) = 1662 J
(B) work (w) = −831 J
(C) heat (q) = 2493 J
(D) the entropy change (ΔS) = 8.52 J K^{-1}
(E) the entropy ($S°$) for this gas at 300 K is 14.52 J mol^{-1} K^{-1}

17. Which of the following compounds (**A-E**) is *not* aromatic?



A　　**B**　　**C**　　**D**　　**E**

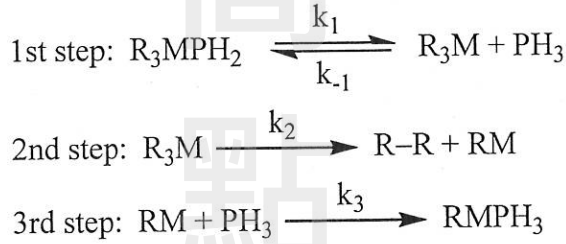
(A) **A**　　(B) **B**　　(C) **C**　　(D) **D**　　(E) **E**

18. Titrating 30.00 mL of a saturated calcium iodate solution requires 27.00 mL of a 0.100 M solution of $Na_2S_2O_3$ according to the equation

$$IO_3^- + S_2O_3^{2-} + H^+ \rightarrow I^- + S_4O_6^{2-} + H_2O \text{ (not balanced)}$$

What is the K_{sp} for $Ca(IO_3)_2$?
(A) 7.14×10^{-8}　　(B) 1.68×10^{-6}　　(C) 2.79×10^{-5}
(D) 4.62×10^{-4}　　(E) 6.23×10^{-2}

19. In an organic solution, an organometallic compound R_3MPH_3 (R = alkyl, M = metal) decomposes into a hydrocarbon R–R and a new compound $RMPH_3$. The mechanism for the reaction was proposed as follows. The first and third steps are fast, whereas the second step is slow. What is the rate law based on the mechanism?



(A) Rate $=(k_1k_3/k_{-1})[R_3MPH_3][RM][PH_3]$
(B) Rate $= [R–R][RM]/[R_3M]$
(C) Rate $= (k_2k_1/k_{-1})[R_3MPH_3]/[PH_3]$
(D) Rate $= k_2[R_3M]/[PH_3]$
(E) Rate $= k_1[R_3MPH_3]$

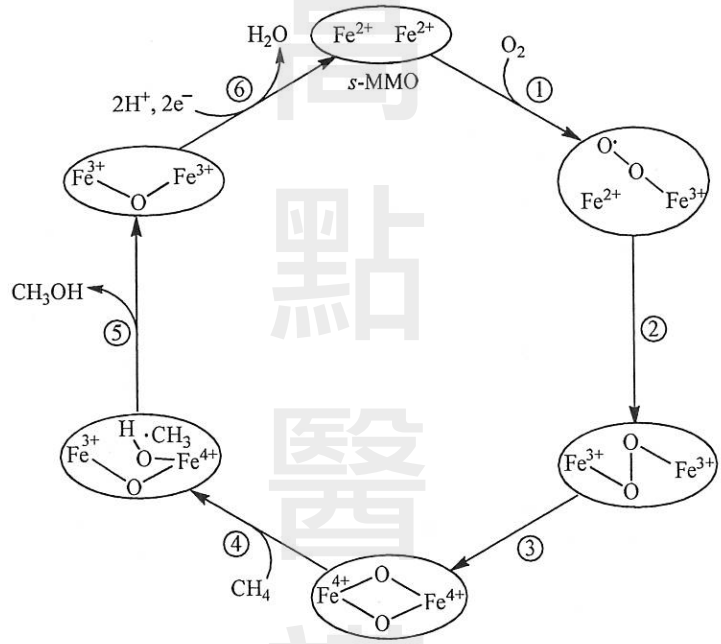
20. The heat required to raise the temperature from 298 K to 398 K for 2 moles of a gas at constant volume is 4155 J. At constant pressure, the internal energy required to heat the same gas from 450 K to 550 K is 4960 J, and the gas does 857 J of work during this expansion. Which of the following statements is correct? ($R = 8.31\ J\ mol^{-1}\ K^{-1}$)

(A) This gas is monatomic.
(B) This gas is not an ideal gas.
(C) The molar heat capacity at constant volume (C_v) is $41.55\ J\ mol^{-1}\ K^{-1}$.
(D) The molar heat capacity at constant pressure (C_p) is $49.60\ J\ mol^{-1}\ K^{-1}$.
(E) The internal energy change is 2078 J when the gas is heated from 273 K to 323 K at constant pressure

21. The molar ratio of Cl^-, Br^-, and I^- in a solution is 2:3:4. Now, if you want to pass Cl_2 into the solution so that the molar ratio of Cl^-, Br^-, and I^- in the solution becomes 4:3:2, what is the molar ratio of Cl_2 to be added and I^- in the original solution?

(A) 1:2　　(B) 1:3　　(C) 1:4　　(D) 1:5　　(E) 1:6

22. Methane monooxygenase (*s*-MMO) contains a dinuclear iron active center and is a catalyst for the oxidation of CH_4 by O_2 to form CH_3OH; the reaction process is shown below. Which of the following statements is *incorrect*?



(A) Theelectronic configuration of the ground state Fe atom is $[Ar]3d^64s^2$.

(B) Step ③ involves the breaking of a non-polar bond and the formation of polar bonds.

(C) Electron transfer occurs between iron and oxygen atoms in each step.

(D) Radical species are produced during the reaction.

(E) The overall reaction shown is $CH_4 + O_2 + 2\,H^+ + 2\,e^- \xrightarrow{s\text{-MMO}} CH_3OH + H_2O$

23. Which pair of the following compounds that measured under the same conditions have the same amplitude of specific rotation but with opposite direction?

(A) *cis*-1,2-dichlorocyclopentane and *trans*-1,2-dichlorocyclopentane

(B) (*2S*, *3R*)-butane-2,3-diol and (*2R*, *3S*)-butane-2,3-diol

(C) *cis*-2-butene and *trans*-2-butene

(D) (*2S*, *3R*)-butane-2,3-diol and (*2R*, *3R*)-butane-2,3-diol

(E) D-glucose and L-glucose

24. (i) The number of the following species which exhibit resonance is ***a***.

O_3, SeO_2, NF_3, N_2O, CCl_4, SCN^-, OF_2

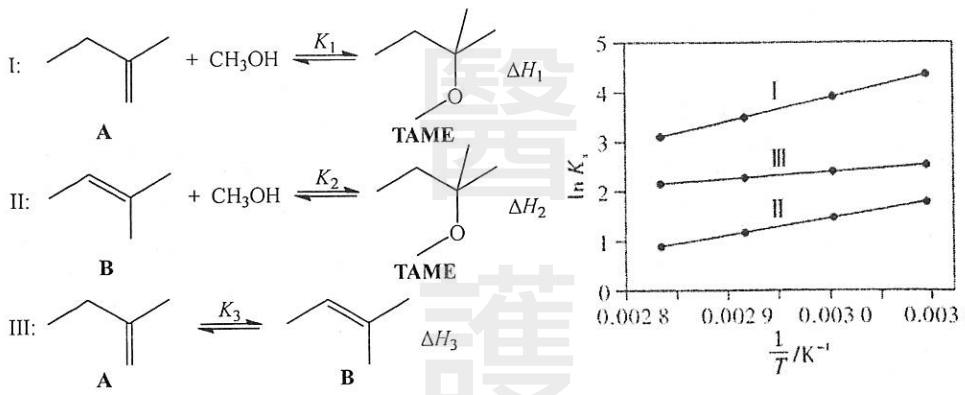
(ii) The number of the following diatomic species which are paramagnetic is ***b***.

B_2, C_2^{2-}, OF, O_2^{2-}, N_2^+, NO^+, F_2

What is (***a*** + ***b***)?

(A) 5　　(B) 6　　(C) 7　　(D) 8　　(E) 9

25. 2-Methoxy-2-methylbutane (TAME) is commonly used as a gasoline additive. With the presence of appropriate catalysts, TAME can be produced by the liquid-liquid reaction between methanol and olefins, in which the following reactions occur simultaneously.



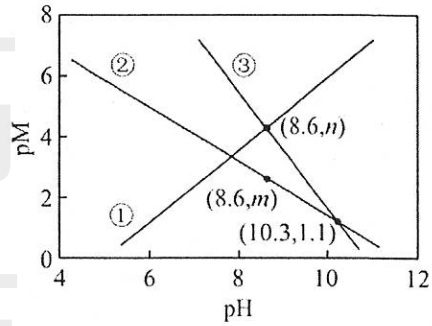
The equilibrium constants K_x, expressed in terms of the amount fraction of the substance, for reactions I, II, and III are shown above. What is the range of values of $\frac{\Delta H_1}{\Delta H_2}$?

(A) < -1　　(B) $-1 \sim 0$　　(C) $0 \sim 1$　　(D) > 1　　(E) $\frac{\Delta H_1}{\Delta H_2} = 1$

26. Consider the reaction 2 X(g) + Y(g) ⇌ 2 Z(g) in a rigid container at 27 °C. The initial concentrations of X and Y are 2.0 mol/L and 3.0 mol/L, and 1.0 mol/L of Z will be produced at equilibrium. If you want to prepare 0.40 atm of Z from an initial pressure of 1.0 atm of X, what would be the approximate initial pressure of Y? (gas constant R = 0.082 atm·L·K^{-1}·mol^{-1})

(A) 1.3 atm　(B) 3.3 atm　(C) 10.2 atm　(D) 21.3 atm　(E) 28.0 atm

27. The formation of stalactite is closely related to the concentration of carbon-containing species formed by the dissolution of $CaCO_3$ in the rocks and CO_2 in the air in natural water bodies. Given that K_{sp} ($CaCO_3$) $= 10^{-8.7}$, pM = −log[M] where M = HCO_3^-, CO_3^{2-}, or Ca^{2+}, the variation of pM with pH in a cave water body at room temperature is shown on the right.



Which of the following is *incorrect*?

(A) ② represents HCO_3^-.

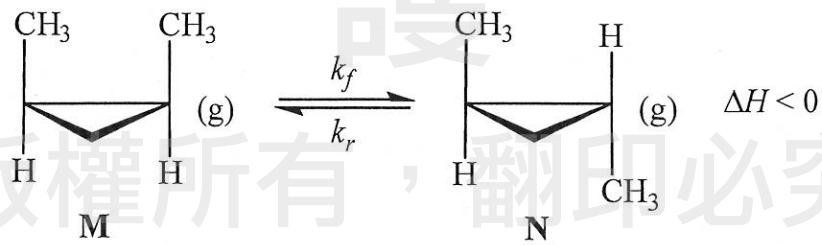
(B) K_{a2} of H_2CO_3 is $10^{-10.3}$.

(C) m = 2.75 and n = 4.35

(D) When pH is 10.3, $[Ca^{2+}] = 10^{-7.6}$ M.

(E) When pH is increased from 4 to 8, $[CO_3^{2-}]$ increases faster than $[HCO_3^-]$.

28. At a certain temperature, *cis*-1,2-dimethylcyclopropane (**M**) and *trans*-1,2-dimethylcyclopropane (**N**) undergo the following transformation.



The rate laws for the reactions can be expressed as $v_f = k_f[\mathbf{M}]$ and $v_r = k_r[\mathbf{N}]$, with k_f and k_r being constants at a given temperature, called the forward and reverse rate constants, respectively, and the equilibrium constant of the reaction, $K = 3$. Which of the following statements is correct?

(A) At this temperature, the conversion of **M** is 66.7%.

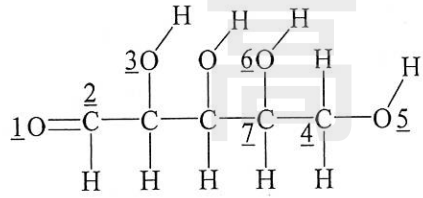
(B) As the temperature increases, both k_f and k_r increase.

(C) At room temperature, **N** is a gas under 1 atm.

(D) **M** is more stable than **N**.

(E) Heating this reaction increases the equilibrium constant K.

29. When the following monosaccharide form furanose, a new bond is formed between which two atoms (use underlined numbers)?



(A) 1–4　　(B) 2–6　　(C) 5–2　　(D) 3–4　　(E) 7–1

30. Consider the complex ions $[Co(NH_3)_6]^{3+}$, $[Co(CN)_6]^{3-}$, and $[CoF_6]^{3-}$. The wavelengths of absorbed electromagnetic radiation for these ions in solution are (in no specific order) 293 nm, 442 nm, and 768 nm. Which of the following statements is correct?

(A) $[Co(NH_3)_6]^{3+}$ absorbs 293-nm electromagnetic radiation.

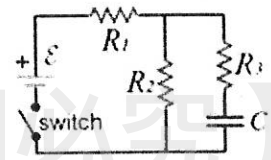
(B) $[Co(CN)_6]^{3-}$ absorbs 442-nm electromagnetic radiation.

(C) $[CoF_6]^{3-}$ absorbs 768-nm electromagnetic radiation.

(D) The solution of $[Co(NH_3)_6]^{3+}$ is blue.

(E) The solution of $[CoF_6]^{3-}$ is red.

31. The capacitor in the figure (right) is initially uncharged. The emf of the battery is $\varepsilon = 10$ volts. The values of the resistors are: $R_1 = R_2 = R_3 = 1\ \Omega$. The capacitor C is 10 μF. The switch is initially open and is closed at $t = 0$. What is the final charge on the capacitor if one waits long enough?



(A) 10 μC　　(B) 50 μC　　(C) 100 μC　　(D) 200 μC　　(E) 0

32. A particle collides with an identical particle at rest relative to an inertial frame S. These two (noninteracting) particles has speed $0.6c$ moving toward each other along the x direction in their center-of-momentum frame (namely, in the inertial frame in which the total momentum of the system vanishes), denoted by S'. What is the speed of frame S' relative to frame S?

(A) $1.2c$　　(B) $\frac{15}{17}c$　　(C) $\frac{\sqrt{3}}{2}c$　　(D) $0.6c$　　(E) $(2-\sqrt{3})c$

33. The wave function of a transverse wave propagating on a rope is $y(x, t) = 5\sin(\pi x + 4\pi t)$, where x and y are measured in meters and t is in seconds. What is the velocity (m/s) of a particle on the rope at $x = 2$ m and $t = 0.5$s?

(A) 0　　(B) −4　　(C) 5π　　(D) 10π　　(E) 20π

34. A conductor of radius r, length l, and resistivity ρ has resistance R. Assume that the volume of this conductor is conserved. What is the new resistance if it is stretched to double its original length?

(A) $\frac{1}{4}$R　　(B) $\frac{1}{2}$R　　(C) R　　(D) 2R　　(E) 4R

35. The molar specific heat at constant volume is C_V, and the molar specific heat at constant pressure is C_P. For an ideal gas at a fixed temperature, which of the following statements is true?

(A) C_P is always greater than C_V, because part of the absorbed heat is used to do work to the environment.

(B) C_P is always greater than C_V, because the environment absorbs additional heat.

(C) C_P is always less than C_V, because part of the absorbed heat is used to do work to the environment.

(D) C_P is always less than C_V, because the environment absorbs additional heat.

(E) There is no certain relation between C_P and C_V.

36. Which of the following statements about the specific heat of an ideal gas is correct?

(A) The specific heat at constant pressure is greater than the specific heat at constant volume because work is done by the gas at constant volume.

(B) The specific heat at constant pressure is greater than the specific heat at constant volume because work must be done by the gas at constant pressure.

(C) The specific heat is greater for a more massive gas.

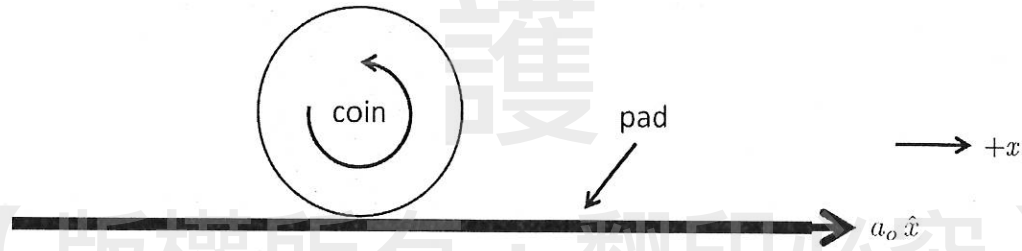
(D) The specific heat is greater at lower temperature.

(E) The specific heat is proportional to the absolute temperature.

37. A neutron has a mass of 1.67×10^{-27} kg. The de Broglie wavelength is 1.4×10^{-10} m. What is the velocity of the neutron? (Plank's constant $h = 6.63 \times 10^{-34}$ J·s)
(A) 1.55×10^{2} m/s (B) 7.01×10^{2} m/s (C) 2.99×10^{6} m/s
(D) 2.83×10^{3} m/s (E) 3.53×10^{3} m/s

38. For designing an anti-reflective coating for a glass surface in an optical device at a free-space wavelength of 552 nm. The refractive index of the glass is 1.50. Determine the minimum thickness (nm) of the optical coating with a refractive index of 1.38.
(A) 276 (B) 184 (C) 138 (D) 100 (E) 92.0

39. A coin of mass m and radius R rolls steadily without slipping on a moving pad. Assume that the coin's face orientation remains fixed and its density is uniform. The coin rolls counter-clockwise and moves in the x-direction as shown in the figure. Suppose the pad is accelerating along the +x-direction with a constant acceleration a_0 with respect to the inertial frame. What is the linear acceleration of the coin with respect to the inertial frame?



(A) $+a_0/3$ (B) $-a_0/3$ (C) $+a_0/2$ (D) $-a_0/2$ (E) 0

40. What is the capacitance C of an isolated conductive spherical shell of radius R in free space with total charge Q uniformly distributed over its surface? (You can think of the second conductor as a hollow conducting shell of infinite radius.)
(A) 0 (B) $4\pi R^2 Q$ (C) $2\pi\varepsilon_0 RQ$ (D) $2\pi\varepsilon_0 R$ (E) $4\pi\varepsilon_0 R$

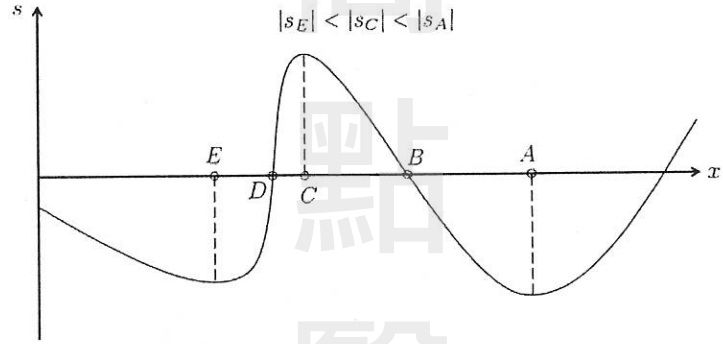
41. A long, straight conductor carries 1.0 A of current. At what distance from the axis of the conductor is the magnetic field caused by the current equal to the Earth's magnetic field (about 0.5 Gauss)? $\mu_0 = 4\pi \times 10^{-7}$ T·m/A
(A) 200 mm (B) 40 mm (C) 20 mm (D) 4 mm (E) 1 mm

42. Which of the following statements is true for one mole of ideal monatomic gases?
(A) For the isobaric process, the change in the internal energy is linearly proportional to the change in the temperature.
(B) For the gas undergoing the adiabatic process, the temperature of the gas remains constant.
(C) For the gas undergoing the isothermal expansion, the internal energy of the gas increases.
(D) For the gas undergoing the adiabatic free expansion process, the temperature of the gas drops.
(E) For the gas undergoing the adiabatic free expansion process, the internal energy of the gas increases.

43. For a monatomic ideal gas undergoing the following three consecutive thermodynamic processes. First, an isochoric process from (P_0, V_0) to ($2P_0$, V_0). Second, an adiabatic free expansion from ($2P_0$, V_0) to (P_0, $2V_0$). Finally, an isobaric process from (P_0, $2V_0$) to (P_0, V_0). Which of the following statements is true?
(A) The entropy of the gas and the entropy of the surroundings increase.
(B) The entropy of the gas increases during the isochoric process.
(C) The entropy of the gas increases during the isobaric process.
(D) The entropy of the gas increases after one cycle is unknown since the gas undergoes the adiabatic free expansion process.
(E) None of the above is true.

44. According to the Drude model, the speed of charge carriers driven in conducting media can be described by the concept of drift velocity v_d under a bias voltage. Also, charge carriers (say, electrons) are used to be treated as free particles like ideal gas molecules that are thermally agitated into random motion with an average velocity v_{avg}. In common situations, what the estimated ratio (in the order of magnitude) of v_d/v_{avg} would be?
(A) 10^{10} or even more　　(B) around 10^5　　(C) about 1
(D) around 10^{-5}　　(E) 10^{-10} or even less

45. For a sound wave travelling in a cylinder along the x-direction, a snapshot of the displacement field of air molecules is shown in the following figure. At which marked position, the sound wave possesses the largest energy density? The wave equation of sound is $\frac{\partial^2 s}{\partial t^2} = v^2 \frac{\partial^2 s}{\partial x^2}$.



(A) The sound wave at A, C, and E all possess the largest energy density.

(B) Only at point A since its amplitude is the largest.

(C) Only at point C since it has the largest curvature.

(D) The sound wave at B and E possess the largest energy density.

(E) Only at point D since it has the largest slope.

46. Gold (Au) and tin (Sn) wires are joined together at both ends. The length ratio of the Au and Sn wires is 1:3 and both wires have the same cross-sectional area. A potential difference of V is applied to the free ends. The ratio of the conductivities of Au and Sn is 5:1 and the ratio of the free electron densities of Au and Sn is 5:2. Which of the following statements is correct?

(A) The resistance of Au and Sn wires has the relation $R_{Au}:R_{Sn} = 1:6$.

(B) The voltage across of Au and Sn wires has the relation $V_{Au}:V_{Sn} = 1:15$.

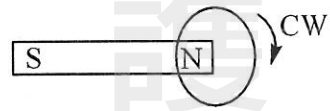
(C) The electric field in Au and Sn wires has the relation $E_{Au}:E_{Sn} = 1:1$.

(D) The drift velocity of electrons in Au and Sn wires has the relation $v_{Au}:v_{Sn} = 1:5$.

(E) None of the above is correct.

47. For a classical electromagnetic plane wave travelling in the x direction in a vacuum (with speed c), the electric field has the form $\vec{E} = E_0 \cos(kx - \omega t)\,\hat{z}$ (V/m). Which of the following statements is true?
(A) The magnetic field oscillates in the x direction with an amplitude $|E_0|/c$ (T).
(B) The energy density of the electromagnetic wave is a constant everywhere in space.
(C) The radiation pressure due to the electromagnetic wave shinning on a wall does not depend on its frequency.
(D) The instantons power per unit area delivered by the electromagnetic wave is a constant.
(E) None of the above is correct.

48. A bar magnet approaches a conducting loop from the left with its north pole directed towards the loop. Considering the effect of electromagnetic induction, the induced current in the loop has the greatest magnitude and a clockwise direction _____.



(A) as the north pole of the magnet approaches the loop
(B) when the north pole has passed through the loop, but the south pole has not yet passed through
(C) when the north pole has passed through and the south pole is about to pass through the loop
(D) as the south pole of the magnet leaves the loop
(E) after the south pole of the magnet is several centimeters to the right of the loop

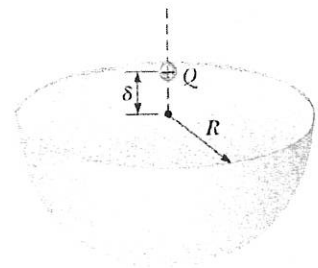
49. Which of the following values is closest to the wavelength (nm) of a photon with energy 1.0 eV? $h = 6.6 \times 10^{-34}$ m^{2}kg/s; $c = 3.0 \times 10^8$ m/s
(A) 1　　(B) 10　　(C) 100　　(D) 1000　　(E) 10000

50. A parallel-plate capacitor has a capacitance of 100 pF, a plate area of 100 cm^2, and the space between the plates is completely filled with a mica dielectric (κ = 5.4). At a potential difference of 50 V, which of the following values is closest to the magnitude of the electric field E in the mica?

(A) 1.0×10^4 *V/m*　　(B) 1.0×10^3 *V/m*　　(C) 1.0×10^2 *V/m*

(D) 1.0×10^1 *V/m*　　(E) 1.0 *V/m*

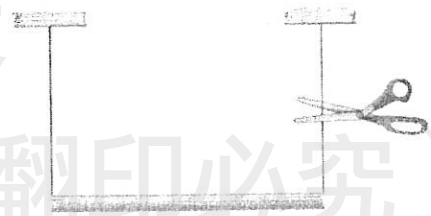
51. As shown in the figure on the right, a particle with charge Q is located at a small distance δ above the center of a plane on a hemisphere of radius R. What is the electric flux through the circular face (of area πR^2) as $\delta \to 0^+$?



(A) $-Q/\varepsilon_0$　　(B) $-\frac{1}{2}(Q/\varepsilon_0)$　　(C) 0

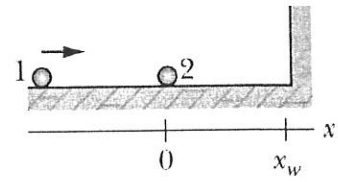
(D) $\frac{1}{2}(Q/\varepsilon_0)$　　(E) Q/ε_0

52. As shown in the figure below, a uniform thin stick of mass M and length L is held vertically by two strings of negligible mass. What is the linear acceleration in the middle of the stick when one of the strings is cut? (Hint: The moment of inertia of the stick is $I = \frac{1}{3}ML^2$ for an axis through one end.)



(A) 1.50 g　　(B) 1.0 g　　(C) 0.75 g　　(D) 0.50 g　　(E) 0.25 g

53. As shown in the figure below, particle **1** of mass m_1 is sliding to the right along the x-axis on a frictionless floor with velocity v_1. When it reaches $x = 0$, it undergoes a one-dimensional elastic collision with stationary particle **2** of mass m_2. When particle **2** reaches the wall at x_w (> 0), it bounces off the wall without losing velocity. What is the condition that particle **2** collides only twice with particle **1**?



(A) $m_2 < m_1$　　(B) $1/3 < m_1/m_2 \leq 1$　　(C) $1/3 \leq m_1/m_2 \leq 1$

(D) $1/3 \leq m_1/m_2 < 1$　　(E) None of the above.

54. Two planets of equal mass orbit a star. Planet ***A*** has a smaller orbital radius than planet ***B***. Which of the following statements is correct?
(A) Planet ***A*** and planet ***B*** have the same mechanical energy (potential energy plus kinetic energy).
(B) Planet ***A*** has less kinetic energy, less potential energy, and less mechanical energy (potential energy plus kinetic energy) than planet ***B***.
(C) Planet ***A*** has more kinetic energy, less potential energy, and less mechanical energy (potential energy plus kinetic energy) than planet ***B***.
(D) Planet ***A*** has more kinetic energy, less potential energy, and more mechanical energy (potential energy plus kinetic energy) than planet ***B***.
(E) Planet ***A*** has more kinetic energy, more potential energy, and more mechanical energy (potential energy plus kinetic energy) than planet ***B***.

55. Which of the following statements is false for one mole of monatomic ideal gas?
(A) By the Equivalence Theorem, we know that the average energy of each molecule in a monatomic gas is $3/2(k_BT)$, where the translation, rotational and vibrational motion each contribute equally to the energy $1/2(k_BT)$.
(B) The isobaric process requires absorbing more heat to increase its temperature by one unit than the isochoric process.
(C) If the pressure of a gas is doubled and the volume is halved, the internal energy of the gas does not change.
(D) During a reversible adiabatic process, the ideal gas law $PV = nRT$ still holds.
(E) None of the above is false.

56. Let us consider aspherical capacitor consisting of two concentric metal spherical shells of radii R_1 and R_2 ($R_1 < R_2$), respectively. Which of the following statements is true?
(A) The capacitance is increased as R_1 reduces.
(B) The capacitance is increased as R_2 increases.
(C) The capacitance increases as R_1 and R_2 increase, while the difference between R_2 and R_1 remains constant.
(D) The potential difference between the two metal spherical shells does not change with the stored charges.
(E) None of the above.

57. Which of the following statements is *not* true?

(A) If an external pressure is applied to a confined fluid which is incompressible, the pressure at every point within the fluid increases by that amount.

(B) The magnitude of pressure exerted by an object on a given surface is equal to its weight acting in the direction perpendicular to that surface. Therefore, like the force vector, pressure is also a vector quantity.

(C) 1 atm is about 14.7 psi.

(D) At any depth in a static fluid, the pressure is the same in all directions at a given depth.

(E) Where fluid velocity is high, pressure is low; where velocity is low, pressure is high.

58. As shown in Figure (b) below, a point-like ball with initial velocity v_0 is inclined at an angle of ψ on the inclined plane and the inclined plane itself is inclined at an angle of ϕ.

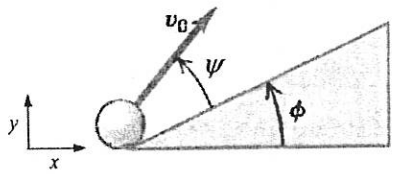


Figure (a)

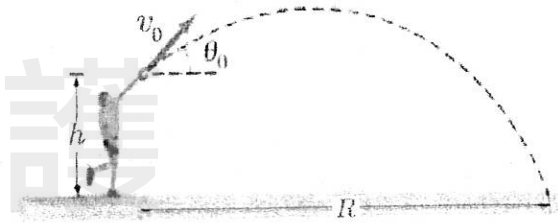


Figure (b)

We know that the distance from the point of launch to the point at which the ball strikes the incline, measured along the incline without taking into account air resistance, is

$$d = \frac{2v_0^2 \cos(\phi + \psi) sin\psi}{g\, cos^2 \phi}$$

Therefore, as shown in Figure (b), what value of θ_0 will maximise R when thrown from a projector with a height h = 2.22 m above the ground and an initial velocity v_0 = 14.0 m/s?

(Hint: Solve a quadratic equation of $\sin\phi$ and, then, take an approximation: $\sin 6° \approx 1/10$.)

(A) smaller than 40°　(B) about 42°　(C) 45°, exactly

(D) about 47°　(E) larger than 50°

59. Which of the following statements about Maxwell's equations is false?
(A) Gauss's law for magnetism implies that there are no magnetic monopoles.
(B) Gauss's law for the electric field shows us that an electric field points away from positive charges and towards negative charges.
(C) Faraday's law states that the rate of change of the magnetic flux through the enclosed surface of a circuit induces a current.
(D) Maxwell's modification to Ampère's law gives that a time-varying electric field results in a circular magnetic field.
(E) None of the above.

60. Which of the following values is closest to the inductance required to store 1.0 kWh of energy in a coil carrying a 200-A current?
(A) 0.1 H　(B) 1 H　(C) 10 H　(D) 40 H　(E) 200 H

國立清華大學 114 學年度學士後醫學系考試 各科試題參考答案

科目名稱：【0103 化學與物理】

題號	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
答案	A	B	B	D	A	C	E	D	D	B	A	E	D	B	B
題號	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
答案	E	D	B	C	E	C	C	E	C	D	E	C	B	B	C
題號	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45
答案	B	B	E	E	A	B	D	D	A	E	D	A	B	E	E
題號	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
答案	B	C	D	D	A	B	C	B	C	A	C	B	B	E	E

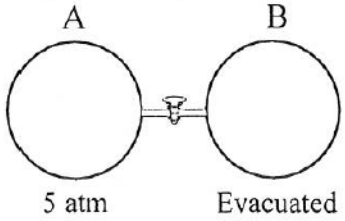
國立清華大學 114 學年度學士後醫學系招生考試試題答案疑義釋疑公告

科目	題號	釋疑答覆	釋疑結果
0103 化學與物理	20	At constant pressure, ΔU still depends only on C_V and ΔT: ΔT = 323 − 273 = 50 K ΔU = nC_VΔT = 2 × 20.775 × 50 = 2077.5 ≈ 2078 J。(E) is correct.	維持原答案

化　學

梁傑(梁家榮)老師提供

1. Consider a system consisting of the following apparatus, in which gas is confined in flask A and there is a vacuum in flask B. The flasks are separated by a valve. Assuming that the flasks are perfectly insulated and will not allow the flow of heat into or out of the flasks to the surroundings. When the valve is opened, gas flows from flask A to flask B. Which of the following statements regarding this process is correct?



(A) No work is performed during the expansion of the gas.
(B) The gas expansion is a nonspontaneous process.
(C) The driving force for this process is enthalpy change.
(D) The internal energy change (ΔE) for this expansion process is > 0.
(E) The entropy change of the surrounding (ΔS_{surr}) for this process is > 0.

(A)

本題屬於絕熱自由膨脹過程，只有(A)正確

2. Given the K_{sp} values for the following compounds:

$PbCrO_4$: 2.0×10^{-16}　　$Zn(OH)_2$: 4.5×10^{-17}

$Pb(OH)_2$: 1.2×10^{-15}　　MnS: 2.3×10^{-13}

Which of the following statements about these compounds is *incorrect*?

(A) The solubility of MnS in water is pH dependent.
(B) $Zn(OH)_2$ has the lowest molar solubility in water.
(C) $Pb(OH)_2$ has the highest molar solubility in water.
(D) $Zn(OH)_2$ is more soluble upon decreasing the pH of solution.
(E) A saturated $PbCrO_4$ solution has a lower $[Pb^{2+}]$ than a saturated $Pb(OH)_2$

(B)

$PbCrO_4$: $S^2 = 2\times10^{-16} \Rightarrow S \approx 10^{-8}$ (溶解度最差，(B)錯誤)

$Zn(OH)_2$: $4S^3 = 4.5\times10^{-17} \Rightarrow S \approx 10^{-6} \sim 10^{-7}$

$Pb(OH)_2$: $4S^3 = 1.2\times10^{-15} \Rightarrow S \approx 10^{-5} \sim 10^{-6}$

MnS: $S^2 = 2.3\times10^{-13} \Rightarrow S \approx 10^{-6} \sim 10^{-7}$

4. Consider the reaction: $a\ X(g) \rightleftharpoons b\ Y(g)$

Each entry in the table below represents the equilibrium partial pressures of X and Y under different initial conditions at the same temperature. The coefficients a and b are the simplest integers. When the equilibrium partial pressure of X is 0.20 atm, the equilibrium partial pressure of Y is n atm. Which of the following statements is true?

P_X (atm)	2.0	1.4	1.0	0.78	0.50	0.20
P_Y (atm)	4.0	2.0	1.0	0.60	0.25	n

(A) $a = 1$ (B) $b = 2$ (C) $n = 0.10$ (D) $a = 2b$ (E) $a + b = 4$

(D)

由於 $P_X=1$ 且 $P_Y=1$ 也是平衡狀態，表示 $K_p=1$

因此：$\frac{4^b}{2^a}=\frac{(2^2)^b}{2^a}=\frac{2^{2b}}{2^a}=1 \Rightarrow a=2b$ (D)正確

備註：由於a=2b，則若b=1，則a=2 ⇒ 符合上表所有資料

若b=2，則a=4

若b=3，則a=6

⋮

} 不符合資料

6. Which of the following statements about electrochemical cells is *incorrect*?

(A) The standard potential ($E°$) in a concentration cell is zero.

(B) In a concentration cell, the higher ion concentration solution is present at the cathode.

(C) At equilibrium, the standard potential ($E°$) in a cell is zero.

(D) The cell potential (E) can determine the spontaneity of a cell.

(E) In a concentration cell, decreasing the anode ion concentration will give rise to larger cell potentials.

(C)

(C)選項錯誤

平衡時，$E_{cell} = 0$ 才對，而不是 $E^\circ_{cell} = 0$

7. Which of the following names for compounds complies to IUPAC nomenclature?

(A) 2,5-pentadiene (B) *cis*-1-butene (C) (*R*)-bromocyclopentane

(D) *trans*-1,1-dichlorocyclohexane (E) propanal

(E)

(A) 

此結構是2,4-pentadiene而不是2,5-pentadiene

(B) 

此結構沒有cis/trans之分，名稱為1-butene

(C) 

此結構沒有R/S之分，名稱為bromocyclopentane

(D) 

此結構沒有cis/trans之分，名稱為1,1-dichlorocyclohexane

9. In preparation for the combustion demonstration, the assistant instructor injected equal molar amount of H_2 and O_2 into the balloon, but the demonstration had to be postponed until the next day due to safety setup problems. During the night, both gases leaked through the pores of the balloon. What is the molar ratio of O_2 to H_2 in the balloon the next day if 30% of the H_2 is leaking?

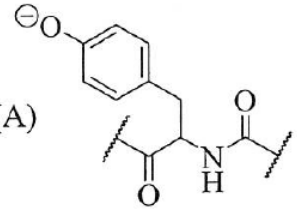
(A) 0.76 (B) 0.95 (C) 1.14 (D) 1.32 (E) 1.60

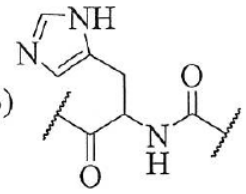
(D)

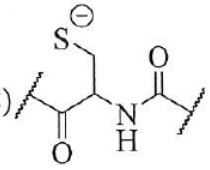
$$\frac{\text{Leaking Rate}(H_2)}{\text{Leaking Rate}(O_2)} = \frac{\sqrt{MW_{O_2}}}{\sqrt{MW_{H_2}}} \Rightarrow \frac{0.3}{\text{Rate}(O_2)} = \frac{\sqrt{32}}{\sqrt{2}} = \frac{4}{1} \Rightarrow \text{Rate}(O_2) = 0.075$$

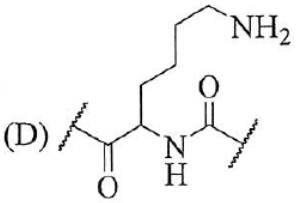
molar ratio of O_2 to H_2 in the balloon : $\frac{O_2}{H_2} = \frac{(1-0.075)}{(1-0.3)} = \frac{1.32}{1}$

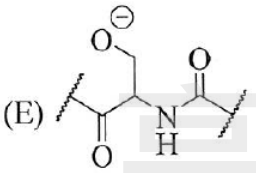
12. Which of the following forms of peptide residues is the most basic?

(A) 

(B) 

(C) 

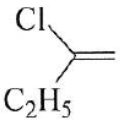
(D) 

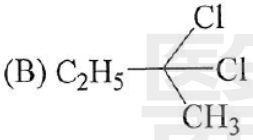
(E) 

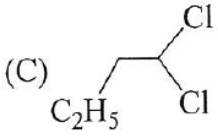
(E)

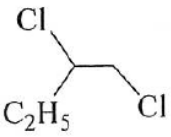
帶負電且不能共振分散負電的氧原子最具鹼性

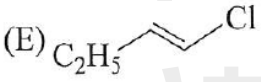
14. What is the major product for following reaction?

(A) 

(B) 

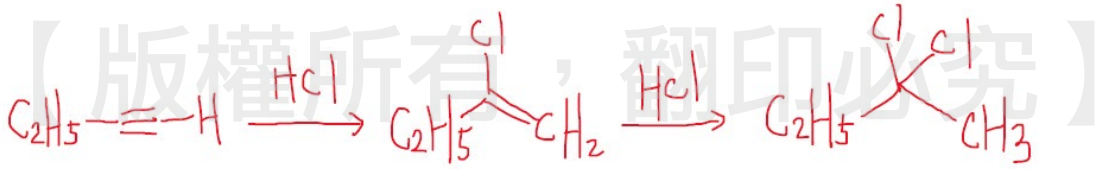
(C) 

(D) 

(E) 

(B)

炔類與 HCl 的親電加成反應遵守 Markovnikov's rule，氫接在多氫碳上為主產物



15. A mineral crystallizes in a cubic closest-packed array of oxygen ions (O^{2-}) with aluminum ions (Al^{3+}) in some of the octahedral holes and magnesium ions (Mg^{2+}) in some of the tetrahedral holes. Which of the following statements about this compound is correct?

(A) The empirical formula is $Al_2Mg_2O_5$.

(B) Half of the octahedral holes are filled with aluminum ions.

(C) One-fourth of the tetrahedral holes are filled with magnesium ions.

(D) There are two oxygen ions in a unit cell.

(E) There are four aluminum ions in a unit cell.

(B)

依照題目敘述

該晶體的單位晶格中含有4個 O^{-2} 、2個 Al^{+3} 、1個 Mg^{+2}

(A)(D)(E)都錯誤，正確的化學式為 Al_2MgO_4

(C)錯誤，tetrahedral hole 只填 1/4

只有(B)正確

19. In an organic solution, an organometallic compound R_3MPH_3 (R = alkyl, M = metal) decomposes into a hydrocarbon R–R and a new compound $RMPH_3$. The mechanism for the reaction was proposed as follows. The first and third steps are fast, whereas the second step is slow. What is the rate law based on the mechanism?

$$\text{1st step: } R_3MPH_2 \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} R_3M + PH_3$$

$$\text{2nd step: } R_3M \xrightarrow{k_2} R\text{–}R + RM$$

$$\text{3rd step: } RM + PH_3 \xrightarrow{k_3} RMPH_3$$

(A) Rate $=(k_1k_3/k_{-1})[R_3MPH_3][RM][PH_3]$

(B) Rate $= [R\text{–}R][RM]/[R_3M]$

(C) Rate $= (k_2k_1/k_{-1})[R_3MPH_3]/[PH_3]$

(D) Rate $= k_2[R_3M]/[PH_3]$

(E) Rate $= k_1[R_3MPH_3]$

(C)

RDS為第二步，因此Rate law為：Rxn Rate $= k_2[R_3M]$ ——— ①

（但 R_3M 為中間物，要改寫方程式）

已知第一步為快速平衡：$k_1[R_3MPH_3] = k_{-1}[R_3M][PH_3]$

$$\Downarrow$$

$$[R_3M] = \frac{k_1[R_3MPH_3]}{k_{-1}[PH_3]} \quad \text{——— ②}$$

將②代入①：$\text{Rxn Rate} = k_2\left(\frac{k_1[R_3MPH_3]}{k_{-1}[PH_3]}\right) = \left(\frac{k_2k_1}{k_{-1}}\right)\left(\frac{[R_3MPH_3]}{[PH_3]}\right)$

20. The heat required to raise the temperature from 298 K to 398 K for 2 moles of a gas at constant volume is 4155 J. At constant pressure, the internal energy required to heat the same gas from 450 K to 550 K is 4960 J, and the gas does 857 J of work during this expansion. Which of the following statements is correct? ($R = 8.31\ J\ mol^{-1}\ K^{-1}$)
(A) This gas is monatomic.
(B) This gas is not an ideal gas.
(C) The molar heat capacity at constant volume (C_v) is 41.55 $J\ mol^{-1}\ K^{-1}$.
(D) The molar heat capacity at constant pressure (C_p) is 49.60 $J\ mol^{-1}\ K^{-1}$.
(E) The internal energy change is 2078 J when the gas is heated from 273 K to 323 K at constant pressure

(E)

298K → 398K：$\Delta E = nC_v\Delta T = 2\times C_v\times(398-298) = 4155 \Rightarrow C_v = 20.78\ (\frac{5}{2}R)$

450K → 550K：$\Delta E = 4960\ J$，$W = -857\ J$

$$\Delta H = \Delta E + \Delta(PV) = \Delta E + P\Delta V = \Delta E + (-W) = nC_p\Delta T$$

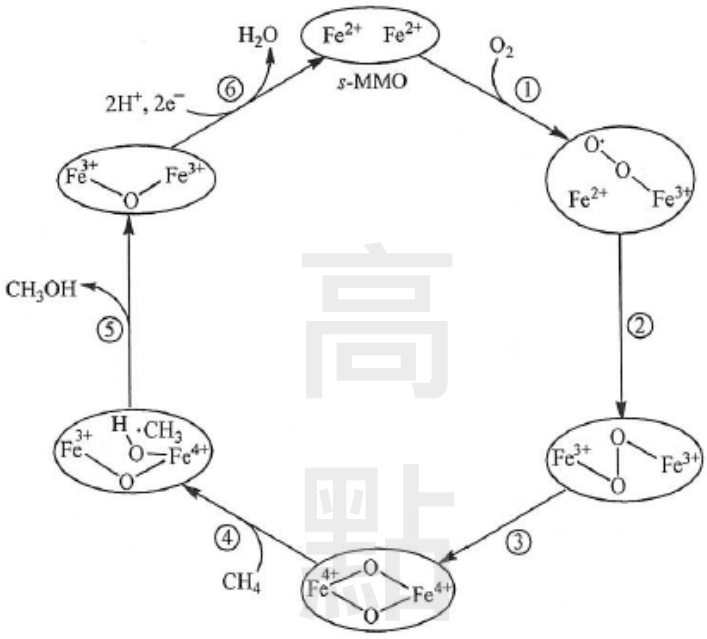
$$\Delta H = 4960 + [-(-857)] = 2\times C_p\times(550-450) \Rightarrow C_p = 29.09\ (\frac{7}{2}R)$$

273K → 323K：$\Delta E = nC_v\Delta T = 2\times 20.78\times(323-273) = 2078\ J$

(A)、(B)錯誤，因為 $C_v \neq \frac{3}{2}R$ 且 $C_p \neq \frac{5}{2}R$，不是單原子氣體，但 $C_v - C_p = R$，是理想氣體

(C)、(D)錯誤，$C_v = 20.78\ \frac{J}{mol\cdot K}$、$C_p = 29.09\ \frac{J}{mol\cdot K}$

22. Methane monooxygenase (*s*-MMO) contains a dinuclear iron active center and is a catalyst for the oxidation of CH_4 by O_2 to form CH_3OH; the reaction process is shown below. Which of the following statements is *incorrect*?



(A) Theelectronic configuration of the ground state Fe atom is $[Ar]3d^64s^2$.

(B) Step ③ involves the breaking of a non-polar bond and the formation of polar bonds.

(C) Electron transfer occurs between iron and oxygen atoms in each step.

(D) Radical species are produced during the reaction.

(E) The overall reaction shown is $CH_4 + O_2 + 2\,H^+ + 2\,e^- \xrightarrow{s\text{-MMO}} CH_3OH + H_2O$

(C)錯誤，step 4 -step 6 的電子轉移並非 oxygen 與 iron

24. (i) The number of the following species which exhibit resonance is ***a***.

O_3, SeO_2, NF_3, N_2O, CCl_4, SCN^-, OF_2

(ii) The number of the following diatomic species which are paramagnetic is ***b***.

B_2, C_2^{2-}, OF, O_2^{2-}, N_2^+, NO^+, F_2

What is $(a + b)$?

(A) 5 (B) 6 (C) 7 (D) 8 (E) 9

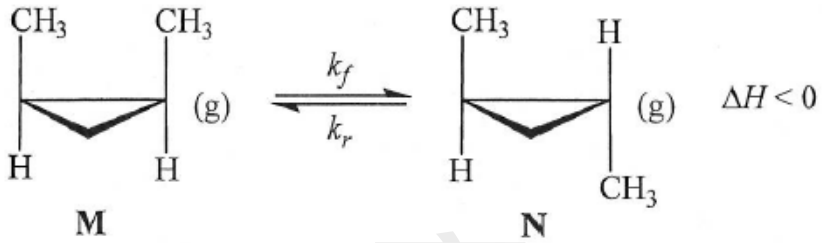
(C)

可畫共振結構者：O_3、SeO_2、N_2O、SCN^- ⟹ $a=4$

順磁性物質：B_2、OF、N_2^+ ⟹ $b=3$

$a+b=7$

28. At a certain temperature, *cis*-1,2-dimethylcyclopropane (**M**) and *trans*-1,2-dimethylcyclopropane (**N**) undergo the following transformation.



M **N**

The rate laws for the reactions can be expressed as $v_f = k_f[\mathbf{M}]$ and $v_r = k_r[\mathbf{N}]$, with k_f and k_r being constants at a given temperature, called the forward and reverse rate constants, respectively, and the equilibrium constant of the reaction, $K = 3$. Which of the following statements is correct?

(A) At this temperature, the conversion of **M** is 66.7%.

(B) As the temperature increases, both k_f and k_r increase.

(C) At room temperature, **N** is a gas under 1 atm.

(D) **M** is more stable than **N**.

(E) Heating this reaction increases the equilibrium constant K.

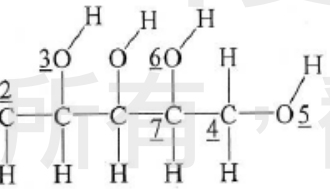
(A)錯誤，conversion of M = 75%

(C)錯誤，室溫下，cpd N 為liquid (bp = 28°C)

(D)錯誤，cpd N較穩定

(E)錯誤，加熱會使平衡常數變小

29. When the following monosaccharide form furanose, a new bond is formed between which two atoms (use underlined numbers)?



(A) 1–4 (B) 2–6 (C) 5–2 (D) 3–4 (E) 7–1

(B)

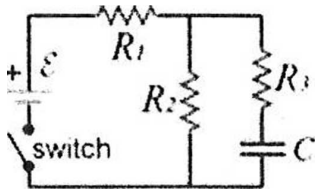
furanose 結構：含有 oxygen 的五員環狀 sugar

物 理

程量子(陳宗德)老師提供

國立清華大學學士後西醫物理試題

1. The capacitor in the figure (right) is initially uncharged. The emf of the battery is $\varepsilon = 10$ volts. The values of the resistors are: $R_1 = R_2 = R_3 = 1\ \Omega$. The capacitor C is 10 μF. The switch is initially open and is closed at $t = 0$. What is the final charge on the capacitor if one waits long enough?



(A) 10 μC (B) 50 μC (C)100 μC (D) 200 μC (E) 0

1. 解：(B)

Long time, 電容器視為斷路，此時 R_1 及 R_2 串聯，$V_2 = 5.0$

電容器之電壓亦為 5.0

由 $Q(t) = C\varepsilon(1 - e^{-\frac{t}{RC}})$

$$Q(\infty) = C\varepsilon = (10 \times 10^{-6})(5) = 50 \times 10^{-6} = 50[\mu C]$$

2. A particle collides with an identical particle at rest relative to an inertial frame S. These two (noninteracting) particles has speed $0.6c$ moving toward each other along the x direction in their center-of-momentum frame (namely, in the inertial frame in which the total momentum of the system vanishes), denoted by S'. What is the speed of frame S' relative to frame S?

(A) $1.2c$ (B) $\frac{15}{17}c$ (C) $\frac{\sqrt{3}}{2}c$ (D) $0.6c$ (E) $(2-\sqrt{3})c$

2. 解：(B)

From S'

$$u_1' = 0.6c,\ u_2' = -0.6c$$

觀察者由 S' 轉換到 S (S' 相對於 S 以 v 前進)

From S

粒子 1 $u_1 = \dfrac{u_1' + v}{1 + \dfrac{u_1' v}{c^2}} = \dfrac{0.6c + v}{1 + \dfrac{(0.6c)v}{c^2}}$

粒子 2 $u_2 = \dfrac{u_2' + v}{1 + \dfrac{u_2' v}{c^2}} = \dfrac{-0.6c + v}{1 + \dfrac{(-0.6c)v}{c^2}} = 0 \Rightarrow v = 0.6c$ 代回粒子 1，則有

$$u_1 = \frac{u_1' + v}{1 + \dfrac{u_1' v}{c^2}} = \frac{0.6c + 0.6c}{1 + \dfrac{(0.6c)(0.6c)}{c^2}} = \frac{15}{17}c$$

3. The wave function of a transverse wave propagating on a rope is $y(x,t) = 5\sin(\pi x + 4\pi t)$, where x and y are measured in meters and t is in seconds. What is the velocity (m/s) of a particle on the rope at x = 2 m and t = 0.5s?

(A) 0 (B) -4 (C) 5π (D) 10π (E) 20π

3. 解：(E)

$$v_y = \frac{\partial y}{\partial t} = 5 \times 4\pi\cos(\pi x + 4\pi t) = 20\pi\cos(\pi x + 4\pi t)$$

$$v_y(2,0.5) = 20\pi\cos(\pi\cdot 2 + 4\pi\cdot 0.5) = 20\pi$$

4. A conductor of radius r, length l, and resistivity ρ has resistance R. Assume that the volume of this conductor is conserved. What is the new resistance if it is stretched to double its original length?

(A) $\frac{1}{4}R$ (B) $\frac{1}{2}R$ (C) R (D) $2R$ (E) $4R$

4. 解：(E)

$$V = \pi r^2 l = \pi(\frac{r}{\sqrt{2}})^2(2l) = V'$$

$$R' = \rho\frac{2l}{\pi(\frac{r}{\sqrt{2}})^2} = 4(\rho\frac{l}{\pi r^2}) = 4R$$

5. The molar specific heat at constant volume is Cv, and the molar specific heat at constant pressure is Cp. For an ideal gas at a fixed temperature, which of the following statements is true?

(A) Cp is always greater than Cv, because part of the absorbed heat is used to do work to the environment.

(B) Cp is always greater than Cv, because the environment absorbs additional heat.

(C) Cp is always less than Cv, because part of the absorbed heat is used to do work to the environment.

(D) Cp is always less than Cv, because the environment absorbs additional heat.

(E) There is no certain relation between Cp and Cv.

5. 解：(A)

$$C_P = \frac{1}{n}(\frac{\Delta Q}{\Delta T})\Big|_P,\ C_V = \frac{1}{n}(\frac{\Delta Q}{\Delta T})\Big|_V$$

$C_P > C_V$, 系統在吸熱時，會有一部分的熱能轉換成對外界作功

6. Which of the following statements about the specific heat of an ideal gas is correct?
(A) The specific heat at constant pressure is greater than the specific heat at constant volume because work is done by the gas at constant volume.
(B) The specific heat at constant pressure is greater than the specific heat at constant volume because work must be done by the gas at constant pressure.
(C) The specific heat is greater for a more massive gas.
(D) The specific heat is greater at lower temperature.
(E) The specific heat is proportional to the absolute temperature.

6. 解：(B)

$$\Delta U = \Delta Q - \Delta W$$
$$nC_V\Delta T = \Delta Q - P\Delta V$$
$$= \Delta Q - nR\Delta T \quad (P\Delta V + V\Delta P = nR\Delta T,\ \Delta P = 0 \Rightarrow P\Delta V = nR\Delta T)$$
$$\Rightarrow \Delta Q = nC_V\Delta T + nR\Delta T = n(C_V + R)\Delta T = nC_P\Delta T$$
$$C_P = C_V + R$$
$C_P > C_V$, 系統在吸熱時，會有一部分的熱能轉換成對外界作功

7. A neutron has a mass of 1.67 x 10^{-27} kg. The de Broglie wavelength is 1.4 x 10^{-10} m. What is the velocity of the neutron? (Plank's constant h = 6.63 x 10^{-34} J-s)
(A) 1.55 x 10^2 m/s (B) 7.01 x 10^2 m/s (C) 2.99 x 10^6 m/s
(D) 2.83 x 10^3 m/s (E) 3.53 x 10^3 m/s

7. 解：(D)

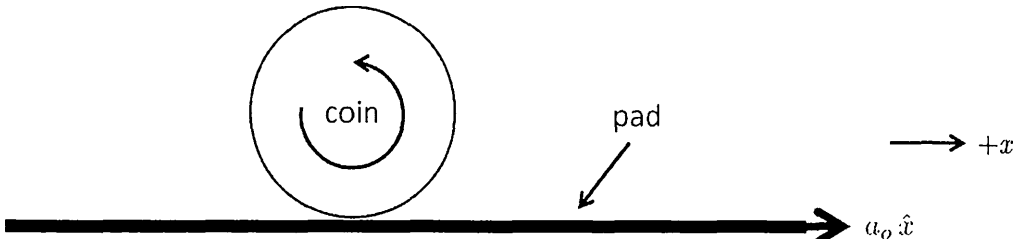
$$\lambda_d = \frac{h}{mv} \Rightarrow 1.4\times10^{-10} = \frac{6.63\times10^{-34}}{(1.67\times10^{-27})v} \Rightarrow v = 2.83\times10^3[m/s]$$

8. For designing an anti-reflective coating for a glass surface in an optical device at a free-space wavelength of 552 nm. The refractive index of the glass is 1.50. Determine the minimum thickness (nm) of the optical coating with a refractive index of 1.38.
(A) 276 (B) 184 (C) 138 (D) 100 (E) 92.0

8. 解：(D)

$$d = \frac{\lambda}{4n_c} = \frac{552}{4\times1.38} = 100[nm]$$

9. A coin of mass m and radius R rolls steadily without slipping on a moving pad. Assume that the coin's face orientation remains fixed and its density is uniform. The coin rolls counter-clockwise and moves in the x-direction as shown in the figure. Suppose the pad is accelerating along the +x-direction with a constant acceleration a_0 with respect to the inertial frame. What is the linear acceleration of the coin with respect to the inertial frame?



(A) $+a_0/3$ (B) $-a_0/3$ (C) $+a_0/2$ (D) $-a_0/2$ (E) 0

9. 解：(A)

$$Rf=\frac{1}{2}mR^2\alpha\Rightarrow\alpha=\frac{2f}{mR}=2\frac{a_c}{R}$$

$\vec{a}$ (p-地)= $\vec{a}$ (p-cm)+ $\vec{a}$ (cm-地)

$\vec{a}$ (p-板)+ $\vec{a}$ (板-地)= $\vec{a}$ (p-cm)+ $\vec{a}$ (cm-地)

$$0+a_0=R\alpha+a\ \text{(cm-地)}$$

$$\Rightarrow a_0=R(\frac{2f}{mR})+a_c$$

$$\Rightarrow a_0=(2a_c)+a_c$$

$$\Rightarrow a_c=\frac{1}{3}a_0$$

10. What is the capacitance C of an isolated conductive spherical shell of radius R in free space with total charge Q uniformly distributed over its surface? (You can think of the second conductor as a hollow conducting shell of infinite radius.)

(A) 0 (B) $4\pi R^2Q$ (C) $2\pi\varepsilon_0RQ$ (D) $2\pi\varepsilon_0R$ (E) $4\pi\varepsilon_0R$

10. 解：(E)

單一導體球的電容 $C=4\pi\varepsilon_0R$

11. A long, straight conductor carries 1.0 A of current. At what distance from the axis of the conductor is the magnetic field caused by the current equal to the Earth's magnetic field (about 0.5 Gauss)? $\mu_0=4\pi\times10^{-7}T\cdot m/A$

(A) 200 mm (B) 40 mm (C) 20 mm (D) 4 mm (E) 1 mm

11. 解：(D)

$$B=\frac{\mu_0 i}{2\pi r}\Rightarrow0.5\times10^{-4}=\frac{4\pi\times10^{-7}\times1}{2\pi r}\Rightarrow r=4\times10^{-3}[m]$$

12. Which of the following statements is true for one mole of ideal monatomic gases?
(A) For the isobaric process, the change in the internal energy is linearly proportional to the change in the temperature.
(B) For the gas undergoing the adiabatic process, the temperature of the gas remains constant.
(C) For the gas undergoing the isothermal expansion, the internal energy of the gas increases.
(D) For the gas undergoing the adiabatic free expansion process, the temperature of the gas drops.
(E) For the gas undergoing the adiabatic free expansion process, the internal energy of the gas increases.

12. 解：(A)

$$\Delta U = \Delta Q - \Delta W$$
$$nC_V\Delta T = \Delta Q - P\Delta V$$
$$= \Delta Q - nR\Delta T \quad (P\Delta V + V\Delta P = nR\Delta T,\ \Delta P = 0 \Rightarrow P\Delta V = nR\Delta T)$$
$$\Rightarrow \Delta Q = nC_V\Delta T + nR\Delta T = n(C_V + R)\Delta T = nC_P\Delta T$$

13. For a monatomic ideal gas undergoing the following three consecutive thermodynamic processes. First, an isochoric process from (P_0, V_0) to ($2P_0$, V_0). Second, an adiabatic free expansion from ($2P_0$, V_0)to (P_0, $2V_0$). Finally, an isobaric process from (P_0, $2V_0$) to (P_0, V_0). Which of the following statements is true?
(A) The entropy of the gas and the entropy of the surroundings increase.
(B) The entropy of the gas increases during the isochoric process.
(C) The entropy of the gas increases during the isobaric process.
(D) The entropy of the gas increases after one cycle is unknown since the gas undergoes the adiabatic free expansion process.
(E) None of the above is true.

13. 解：(B)

定容過程 $\Delta S = nC_V \ln\left|\frac{T_f}{T_i}\right| = nC_V \ln\left|\frac{\frac{(2P_0)(V_0)}{nR}}{\frac{(P_0)(V_0)}{nR}}\right| = nC_V \ln|2| > 0$

等壓過程 $\Delta S = nC_P \ln\left|\frac{T_f}{T_i}\right| = nC_P \ln\left|\frac{\frac{(P_0)(V_0)}{nR}}{\frac{(P_0)(2V_0)}{nR}}\right| = -nC_P \ln|2| < 0$

自由膨脹經過一個循環或宇宙熵皆不變

14. According to the Drude model, the speed of charge carriers driven in conducting media can be described by the concept of drift velocity v_d under a bias voltage. Also, charge carriers (say, electrons) are used to be treated as free particles like ideal gas molecules that are thermally agitated into random motion with an average velocity v_{avg}. In common situations, what the estimated ratio (in the order of magnitude) of v_d/v_{avg} would be?

(A) 10^{10} or even more (B) around 10^5 (C) about 1

(D) around 10^{-5} (E) 10^{-10} or even less

14. 解：(E)

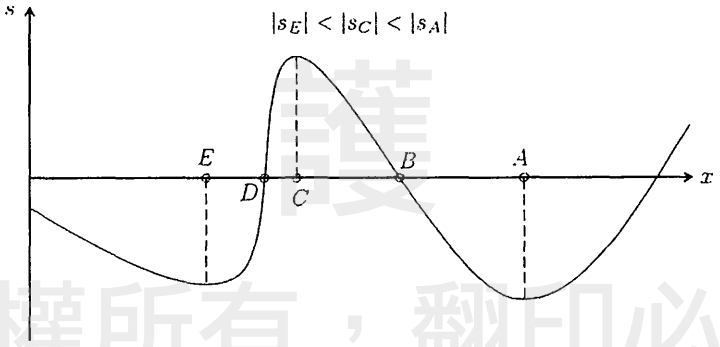
$$v_{av} \cong \sqrt{\frac{3k_BT}{m_e}} = \sqrt{\frac{3\times(1.38\times10^{-23})\times300}{9.11\times10^{-31}}} \approx 10^5[m/s]$$

$$J = \sigma E = nqv_d$$

$$v_d = \frac{\sigma}{nq}E \equiv \eta E = \eta\frac{V}{d} \approx 10^{-3}(\frac{1}{1}) = 10^{-3}$$ (For Cu電子遷移率 $\eta = 10^{-3}$)

$$\frac{v_d}{v_{av}} = \frac{10^{-3}}{10^5} = 10^{-8}$$ 亦可能更小

15. For a sound wave travelling in a cylinder along the x-direction, a snapshot of the displacement field of air molecules is shown in the following figure. At which marked position, the sound wave possesses the largest energy density? The wave equation of sound is $\frac{\partial^2 s}{\partial t^2} = v^2\frac{\partial^2 s}{\partial x^2}$.



(A) The sound wave at A, C, and E all possess the largest energy density.

(B) Only at point A since its amplitude is the largest.

(C) Only at point C since it has the largest curvature.

(D) The sound wave at B and E possess the largest energy density.

(E) Only at point D since it has the largest slope.

15. 解：(E)

最大的單位體積的能量（能量密度）$u = \frac{U}{V} \approx \frac{s^2}{V}$

會出在在分子移動的範圍很小（體積很小），振幅很大，$\frac{\partial s}{\partial x} > 0$

此時空氣分子被壓縮