單選題：共 40 題，每題 2.5 分，答錯倒扣 2 分，倒扣至本大題(即單選題) 0 分為止。

1. Determine the sign of ΔS_{sys} for each chemical reaction. Which one is **positive**?

   (A) $Mg(s) + Cl_2(g) \rightarrow MgCl_2(s)$
   (B) $2H_2S(g) + 3O_2(g) \rightarrow 2H_2O(g) + 2SO_2(g)$
   (C) $2O_3(g) \rightarrow 3O_2(g)$
   (D) $HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$
   (E) $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

2. To inflate a balloon, you must do pressure–volume work on the surroundings. If you inflate a balloon from a volume of 0.100 L to 1.85 L against a constant external pressure of 1.00 bar, how much work is done (in joules)?

   (A) –1.75　(B) –17　(C) –175　(D) +17　(E) +175

3. Lighters are usually fueled by butane (C_4H_{10}). When 2.00 mol of butane burns at constant pressure, it produces 5316 kJ of heat and does 6.00 kJ of work. What are the values of ΔH and ΔU for the combustion of one mole of butane?

   (A) $\Delta H = -2658$ kJ; $\Delta U = -2655$ kJ
   (B) $\Delta H = -2658$ kJ; $\Delta U = -3$ kJ
   (C) $\Delta H = -2658$ kJ; $\Delta U = -2661$ kJ
   (D) $\Delta H = 5316$ kJ; $\Delta U = 5322$ kJ
   (E) $\Delta H = -5316$ kJ; $\Delta U = -5322$ kJ

4. A strip of copper is placed in a 1 M solution of copper nitrate, and a strip of silver is placed in a 1 M solution of silver nitrate. The two metal strips are connected to a voltmeter by wires, and a salt bridge connects the solutions. The following standard reduction potentials apply:

   $Ag^+(aq) + e^- \rightarrow Ag(s)$　　$E° = +0.80$ V
   $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$　　$E° = +0.34$ V

   When the voltmeter is removed and the two electrodes are connected by a wire, which of the following does **not** take place?

   (A) Negative ions pass through the salt bridge from the silver half-cell to the copper half-cell.
   (B) Some positive copper ions pass through the salt bridge from the copper half-cell to the silver half-cell.
   (C) The silver electrode increases in mass as the cell operates.
   (D) Electrons flow in the external circuit from the copper electrode to the silver electrode.
   (E) There is a net general movement of silver ions through the salt bridge to the copper half-cell.

5. Which of the following statements is true?

   (A) We can determine the exact location of an electron if we know its energy.
   (B) Ni has 2 unpaired electrons in its 3*d* orbitals in its ground state.
   (C) An electron in a 2*s* orbital can have the same *n*, *l*, and m_l quantum numbers as an electron in a 3*s* orbital.
   (D) Only three quantum numbers are needed to uniquely describe an electron.
   (E) In the building up of atoms, electrons occupy the 4*f* orbitals before the 6s orbitals.

注意：背面有試題

6. A fuel cell designed to react grain alcohol with oxygen has the following net reaction:

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

The maximum work that 2.00 mol of alcohol can yield by this process is 2640 kJ. What is the theoretical maximum voltage this cell can achieve? (Faraday constant = 96500 C mol^{-1})

(A) 1.14 V　(B) 2.28 V　(C) 13.7 V　(D) 2.01 V　(E) 0.760 V

7. The elements of Group 5A, the nitrogen family, form compounds with hydrogen that have the boiling points listed below.

SbH_3 –17°C, AsH_3 –55°C, PH_3 –87°C, NH_3 –33°C

The first three elements illustrate a trend where the boiling point increases as the mass increases; however, ammonia (NH_3) does not follow the trend because of

(A) ionic bonding.　(B) hydrogen bonding.　(C) metallic bonding.
(D) dipole-dipole attraction.　(E) London dispersion forces.

8. The rate constant of a reaction is measured at different temperatures. A plot of the natural log of the rate constant as a function of the inverse of the temperature (in kelvins) yields a straight line with a slope of -9.74×10^3 K. What is the activation energy (E_a) for the reaction?

(A) –81 kJ/mol　(B) 81 kJ/mol　(C) 1.2 kJ/mol　(D) –1.2 kJ/mol　(E) 1.2 kcal/mol

9. The first-order decay of radon has a half-life of 3.823 days. How many grams of radon remain after 7.65 days if the sample initially weighs 500.0 grams?

(A) 4.21 g　(B) 250 g　(C) 109.6 g　(D) 100 g　(E) 125 g

10. A metal crystallizes in a body-centered cubic unit cell with an edge length of 1.95×10^2 pm. Assume the atoms in the cell touch along the cube diagonal. What will be the percentage of empty volume in the unit cell?

(A) 68.0%　(B) 0.0%　(C) 45.0%　(D) 32.0%　(E) 26.0%

11. Which one of the following statements about solid Cu (face-centered cubic unit cell) is **incorrect**?

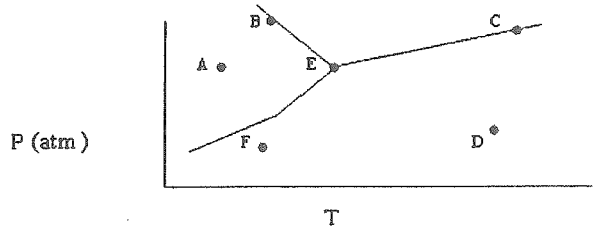
(A) There are two atoms per unit cell.
(B) The solid has a cubic closest-packed structure.
(C) It will conduct electricity.
(D) The number of atoms surrounding each Cu atom is 12.
(E) The length of a face diagonal is four times the Cu radius.

12. The molar mass of a metal (M) is 50.9 g/mol; it forms a chloride of unknown composition. Electrolysis of a sample of the molten chloride with a current of 6.42 A for 23.6 minutes produces 1.20 g of M at the cathode. Determine the empirical formula of the chloride. (Faraday constant = 96500 C mol^{-1})

(A) MCl　(B) MCl_2　(C) MCl_3　(D) MCl_4　(E) MCl_5

注意：背面有試題

13. Based on the phase diagram shown below, which of the following statements are correct?
I. Sublimation occurs at a point that falls along a straight line from point A to point F.
II. C and E represent points where the gas and liquid phases are in equilibrium.
III. Molecules at point D have a greater average kinetic energy than those at point F.
IV. The temperature at point E is called the critical temperature of the compound.



(A) II, III, IV　(B) I, II, III　(C) I, III　(D) II, III　(E) I, II, III, IV

14. Continue from the previous problem. What is the number of degrees of freedom for the one component system at point D on the phase diagram according to Gibbs phase rule?

(A) 1　(B) 2　(C) 3　(D) 4　(E) 5

15. For each of the following solutions, would you expect it with Raoult's law to be relatively ideal, to show a positive deviation, or to show a negative deviation from the ideal behavior?
(I) Ethanol–hexane　(II) Benzene–toluene　(III) Acetone–CS_2

(A) (I) ideal solution	(II) Negative	(III) Positive
(B) (I) Positive	(II) ideal solution	(III) Positive
(C) (I) Positive	(II) ideal solution	(III) Negative
(D) (I) Negative	(II) Positive	(III) ideal solution
(E) (I) Negative	(II) ideal solution	(III) Positive

16. Calculate the freezing point of 2.0 g $Al(NO_3)_3$ in 30. g H_2O. (Assume complete dissociation and ideal solution.)
(Note: K_f for water = 1.86 °C/m and $Al(NO_3)_3$ = 213 g mol^{-1})

(A) –0.059 °C　(B) 2.33 °C　(C) –2.95 °C　(D) –1.75°C　(E) –2.33 °C

17. The vapor pressure of a solution containing 92.3 g glycerin ($C_3H_8O_3$ m.w. = 92.09 g mol^{-1}) in 161.2 g ethanol (C_2H_5OH m.w. = 46.07 g mol^{-1}) is 117 torr at 40°C. Calculate the vapor pressure of pure ethanol at 40°C assuming that glycerin is a nonvolatile, nonelectrolyte solute in ethanol and the solution is an ideal solution.

(A) 139 torr　(B) 230 torr　(C) 452 torr　(D) 151 torr　(E) 525 torr

18. The valence electron configuration of an element X is $ns^2(n-1)d^{10}np^2$. To which group in periodic table does X belong?

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

19. Which element has the greatest second ionization energy?

(A) Na　(B) Ca　(C) K　(D) Mg　(E) Zn

注意：背面有試題

20. A polished metal surface requires 1.75×10^{-19} J to remove electrons via the photoelectric effect. When photons with a wavelength of 237 nm strike the surface, what will be the kinetic energy of the ejected electrons? $h = 6.626 \times 10^{-34}$ J·s, $c = 2.998 \times 10^{8}$ m/s

(A) 1.75×10^{-19} J　(B) 1.01×10^{-18} J　(C) 8.39×10^{-19} J
(D) 6.64×10^{-19} J　(E) none of the above

21. For a solution of IF_5 molecules, its low temperature ^{19}F nuclear magnetic resonance (NMR) spectrum should exhibit which of the following patterns? (^{19}F is 100% abundant with a nuclear spin of ½; ignore any effects due to magnetic coupling to iodine nuclei.)

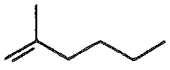
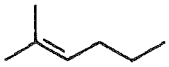
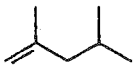
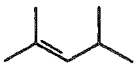
(A) One singlet
(B) One doublet
(C) One sextet
(D) One triplet with an integrated intensity of three and one quartet with an integrated intensity of two
(E) One doublet with an integrated intensity of four and one quintet with an integrated intensity of one

22. For phosphoric acid, $K_{a,1} = 7.6 \times 10^{-3}$, $K_{a,2} = 6.2 \times 10^{-8}$, $K_{a,3} = 4.8 \times 10^{-13}$. In order of decreasing concentrations, which of the following is correct about the concentration of the listed species present in a solution of H_3PO_4 at pH = 8?

I. $[PO_4^{3-}]$　II. $[HPO_4^{2-}]$　III. $[H_2PO_4^{-}]$　IV. $[H_3PO_4]$

(A) I > II > III > IV　(B) I > III > IV > II　(C) III > II > IV > I
(D) IV > I > III > II　(E) IV > III > II > I

23. A certain alkene (C_7H_{14}) exhibits seven signals in its proton-coupled ^{13}C nuclear magnetic resonance spectrum. Of the seven signals, two are quartets, one is a singlet, and four are triplets. Which of the following structures is consistent with these data?

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

24. When 3.00 grams of a nonelectrolyte is dissolved in 100. grams of water, the freezing point of the resulting solution is –0.465°C. What is the molecular weight of the nonelectrolyte? K_f for water is 1.86 °C kg/mol

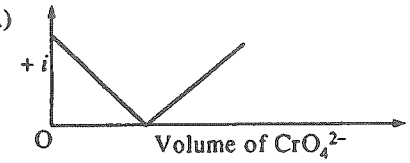
(A) 25.9 grams/mole　(B) 34.7 grams/mole　(C) 120. grams/mole
(D) 168 grams/mole　(E) 259 grams/mole

注意：背面有試題

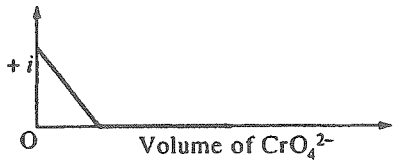
25. $Pb^{2+}(aq) + CrO_4^{2-}(aq) \rightarrow PbCrO_4(s)$

The amperometric titration of Pb^{2+} with CrO_4^{2-} is carried out at an applied potential where both ions are reducible. The reaction is shown above. The titration curve would resemble most closely which of the following?

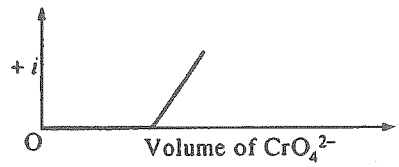
(A)



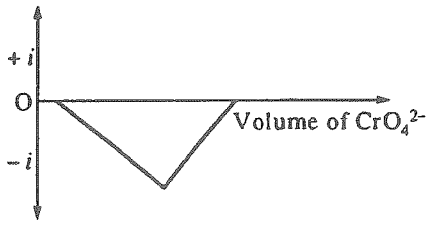
(B)



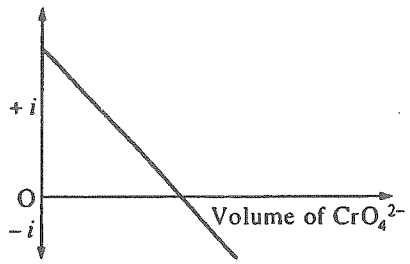
(C)



(D)



(E)



26. The crystals of Na_2O exhibit an antifluorite structure with a coordination number of 4 for the cation. What must be the coordination number of the anion?

(A) 2　(B) 4　(C) 6　(D) 8　(E) 10

27. Which of the following statements concerning hemoglobin is correct?

(A) Oxygen binds to the porphyrin ligands of the heme groups.
(B) Carbon monoxide is toxic because it degrades the heme groups in hemoglobin.
(C) The four heme subunits of hemoglobin exhibit cooperativity in their binding of oxygen.
(D) The binding of oxygen by hemoglobin is pH insensitive.
(E) Hemoglobin binds O_2 irreversibly.

28. Which of the following offers the best combination of reactants to give the highest yield of tert-butyl methyl ether, $(CH_3)_3COCH_3$?

(A) $(CH_3)_3C{=}CH_2 + NaOCH_3$　(B) $(CH_3)_3CHCH_2I + NaOCH_3$　(C) $(CH_3)_3CBr + KOCH_3$
(D) $(CH_3)_3CONa + CH_3OH$　(E) $(CH_3)_3COK + CH_3I$

29. Which of the following reactions produces a colored solution?

(A) $Ca^{2+}(aq) + CO_3^{2-}(aq)$　(B) $Ni(s) + HCl(aq)$　(C) $P_4O_{10}(s) + H_2O$
(D) $KIO_4(s) + H_2O$　(E) $Zn(s) + H_3O^+(aq)$

注意：背面有試題

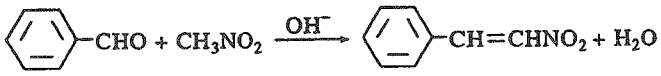
30. The energy of the first triplet excited state is lower than that of the first singlet excited state for ethylene. What is the correct explanation for it?

(A) the more unpair electrons the more stable a molecule
(B) only the singlet excited state has electron(s) in antibonding orbital(s)
(C) the triplet excited state has a larger bond order
(D) the wavefunction is antisymmetric with respect to electron interchange.
(E) Hund's rule requires that the electrons are filled parallel first.

31. $NCCH_2CH_2CN \rightarrow H_2NCCH_2CH_2CNH_2$
Which of the following terms describes a useful method of carrying out the reaction above?
(A) Reduction (B) Acylation (C) Hydrolysis (D) Alkylation (E) Esterification

32. $Hg_2Cl_2(s) + 2\ NH_3(aq) \rightarrow HgNH_2Cl(s) + Hg(l) + NH_4^+(aq) + Cl^-(aq)$
Which of the following conclusions can be drawn from the equation above?

(A) Chloride ions have undergone oxidation.
(B) Nitrogen in some of the ammonia molecules has been reduced and the rest of the nitrogen has been oxidized.
(C) The nitrogen in all of the ammonia molecules has undergone reduction.
(D) The reaction is not an oxidation-reduction reaction.
(E) Mercury(I) has undergone both oxidation and reduction.

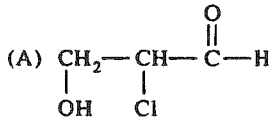
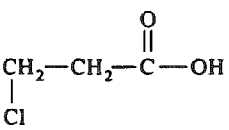
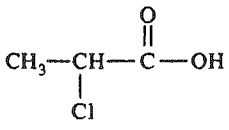
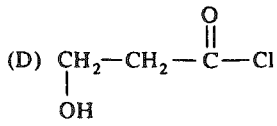
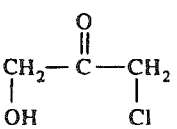
33. 
Which of the following best describes a key step in the mechanism for the reaction above?

(A) Nucleophilic attack by a resonance-stabilized carbanion at a carbonyl carbon
(B) Electrophilic attack by a Lewis acid at a carbonyl carbon
(C) Free radical substitution at a carbonyl carbon
(D) Carbene insertion at a carbonyl carbon
(E) Nucleophilic aromatic substitution

34. If the signal-to-noise ratio for a recorded spectrum is 5, what is the signal-to-noise ratio for the average of 16 spectra recorded in the same manner?

(A) 4 (B) 5 (C) 20 (D) 40 (E) 80

35. An unknown organic substance of molecular formula $C_3H_5O_2Cl$ was found to exhibit the following spectral properties:
IR: (dilute CCl_4 solution) 2900 cm^{-1} (broad); 1710 cm^{-1} (strong)
NMR: (CCl_4 solution) singlet at δ 12.0, triplet at δ 3.7, triplet at δ 2.8
Which of the following structural formulas is consistent with these data?

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

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36. Which of the following statements best describes a key step in the mechanism of the reaction between benzene and bromine in the presence of $FeBr_3$?

(A) A bromide ion attacks benzene in the slow step.
(B) $FeBr_3$ forms a π-complex with benzene.
(C) A complex of $FeBr_3$ and Br_2 reacts with benzene.
(D) Br_2 adds to a double bond of benzene.
(E) In a concerted process, Br_2 attacks benzene, displacing a proton and producing bromobenzene.

37. According to the 18-electron rule, which of the following compounds would be expected to be stable? (Atomic numbers: V = 23, Mn = 25, Fe = 26, Ni = 28, Co = 27)

(A) $V(CO)_5$　(B) $Fe(CO)_5^-$　(C) $Ni(CO)_5$　(D) $Co(CO)_5$　(E) $Mn_2(CO)_{10}$

38. In reverse-phase, high-performance liquid chromatography, the retention time of an analyte is influenced by all of the following **EXCEPT** the

(A) column length　(B) wavelength used in the detection　(C) composition of the mobile phase
(D) composition of the stationary phase　(E) temperature

39. The reduction potential of the saturated calomel electrode is +0.242 V above the standard hydrogen electrode. The reduction potential of an electrode measured relative to a saturated calomel electrode is –0.694 V. What is the reduction potential of this same electrode relative to the standard hydrogen electrode?

(A) –0.936 V　(B) –0.452 V　(C) 0.242 V　(D) 0.452 V　(E) 0.936 V

40. Which of the following statements is correct about electron spins?

(A) They are inseparable from the wavefunction in Schrodinger's equation
(B) Two electrons with the same spin can occupy the same quantum state
(C) They define the interaction of electrons with external electric field
(D) They are classic effect describable by Schrodinger's equation
(E) They give rise to the fine structures in hydrogen emission spectra

類組：化學類　科目：綜合化學(1001)

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