Physical constants

Bohr radius:	$a_0 = 5.29 \times 10^{-11}$ m;	Boltzmann's constant:	$k_B = 1.38 \times 10^{-23}$ J K^{-1}
Electron charge:	$e = 1.60 \times 10^{-19}$ C;	Faraday constant:	$F = 9.65 \times 10^4$ C mol^{-1}
Planck's constant:	$h = 6.63 \times 10^{-34}$ J s;	Speed of light in vacuum:	$c = 3.00 \times 10^8$ m s^{-1}
Mass of electron:	$m_e = 9.11 \times 10^{-31}$ kg;	Mass of proton:	$m_p = 1.67 \times 10^{-27}$ kg
Mass of neutron:	$m_n = 1.67 \times 10^{-27}$ kg		

Universal gas constant: $R = 8.31$ Jmol^{-1}K^{-1} = 0.082 L atm mol^{-1} K^{-1}

$\ln 2 = 0.6931$; $\ln 3 = 1.0986$; $\ln 7 = 1.9459$; $\pi = 3.14$

一、單選題，共 40 題，每題 2.5 分，答錯不倒扣

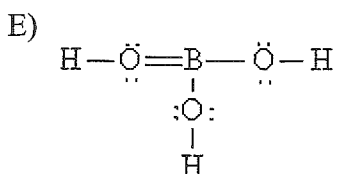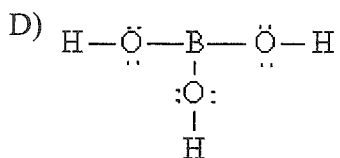1. Iron oxide can be reduced to iron by a reaction with carbon to form carbon monoxide

$$Fe_2O_3(s) + 3C(s) \rightarrow 2Fe(s) + 3CO(g)$$
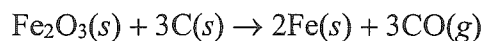
If 95.0 grams of iron oxide is reacted with excess carbon yields 63.0 g of iron, what is the percent yield of this reaction ?

A) 100%   B) 95%   C) 66%   D) 59%   E) 12%

2. The Lewis structure for H_3BO_3 is

A)

B)

C)

D)

E)
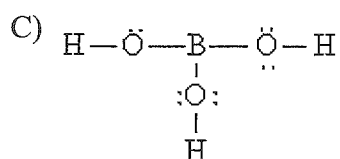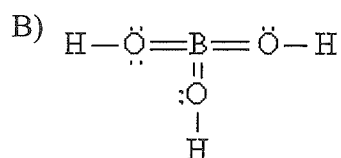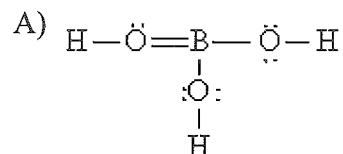
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3. The energy expressions for the electrons in the He^+ ion and the hydrogen atom are

$E_n (H) = -a/n^2$ and $E_n (He^+) = -4a/n^2$

Which of the following statements is(are) correct?

  I. For the transitions $n_1 \rightarrow n_2$, the frequency is larger for H than for He^+.

  II. The first ionization energy of the H atom is smaller than the second ionization
    energy of the He atom.

  III. The 1s orbital in He^+ is larger (in the sense that the probability density is
    shifted outward) than the 1s orbital in H.

 A) I only B) II only C) III only D) I and II only E) I, II, and III

4. One mole of an ideal gas at 25°C is expanded isothermally from 5.0 L to 10.0 L under such conditions that no work is produced in the surroundings. Which statement is correct?

A) $\Delta S_{gas} = 0$

B) $\Delta S_{gas} = R\ln2/298$

C) $\Delta S_{univ} = 0$

D) $\Delta S_{surr} = 0$

E) $\Delta S_{gas} = \Delta S_{surr}$

5. Which of the following statements is true?

A) We can determine the exact location of an electron if we know its energy.

B) An electron in a 2s orbital can have the same n, l, and m_l quantum numbers as an electron in a 3s orbital.

C) Ni has 2 unpaired electrons in its 3d orbitals.

D) In the building up of atoms, electrons occupy the 4f orbitals before the 6s orbitals.

E) Only three quantum numbers are needed to uniquely describe an electron.

6. 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
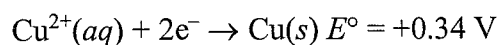
When the voltmeter is removed and the two electrodes are connected by a wire, which of the following does *not* take place?

A) Electrons flow in the external circuit from the copper electrode to the silver electrode.

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B) The silver electrode increases in mass as the cell operates.

C) There is a net general movement of silver ions through the salt bridge to the copper half-cell.

D) Negative ions pass through the salt bridge from the silver half-cell to the copper half-cell.

E) Some positive copper ions pass through the salt bridge from the copper half-cell to the silver half-cell.

7. Consider the molecular-orbital energy-level diagrams for O_2 and NO. Which of the following is true?

  I.   Both molecules are paramagnetic.

  II.   The bond strength of O_2 is greater than the bond strength of NO.

  III. NO is an example of a homonuclear diatomic molecule.

  IV.   The ionization energy of NO is smaller than the ionization energy of NO^+.

  A) I only   B) I and II only   C) I and IV   D) II and III   E) I, II, and IV

8. The reaction $2NO \rightarrow N_2 + O_2$ has the following rate law:

$$\frac{\Delta[NO]}{\Delta t} = 2k[NO]^2$$

After a period of 2.0×10^3 s, the concentration of NO falls from an initial value of 2.8×10^{-3} mol/L to 2.0×10^{-4} mol/L. What is the rate constant, k?

A) 7.2×10^{-2} M^{-1}/s

B) 1.7×10^{-4} M^{-1}/s

C) 4.0×10^{-4} M^{-1}/s

D) 4.0×10^{-7} M^{-1}/s

E) 3.6×10^{-2} M^{-1}/s

9. The following data were collected for the decay of HO_2 radicals.

Time	$[HO_2]$	Time	$[HO_2]$
0 s	1.0×10^{11} molec/cm^3	14 s	1.25×10^{10} molec/cm^3
2 s	5.0×10^{10} molec/cm^3	30 s	6.225×10^{9} molec/cm^3
6 s	2.5×10^{10} molec/cm^3		

Which of the following statements is true?

A) The decay of HO_2 occurs by a first-order process.

B) The half-life of the reaction is 2 ms.

C) A plot of ln $[HO_2]$ versus time is linear with a slope of $-k$.

D) The rate of the reaction increases with time.

E) A plot of $1/[HO_2]$ versus time gives a straight line.

10. Which of the following best describes the lanthanide contraction?

A) *f*-orbitals are more directional than *d*-orbitals and therefore less effective at screening nuclear charge

B) *f*-orbitals are more diffuse than *d*-orbitals and therefore less effective at screening nuclear charge

C) the increase in atomic and ionic radii as one goes from left to right across the lanthanides

D) a and c

E) b and c

11. According to crystal field theory, how many unpaired electrons are present in the complex ion $[Fe(H_2O)_6]^{2+}$? The water molecules are weak field ligands.

A) 1   B) 2   C) 3   D) 4   E) 5

12. A complex ion is a square planar complex. It has a d^8 electron configuration. What is the most reasonable *d* orbital scheme for this complex?

A)

B)

C)

D)

E)

13. Helium effuses through a small opening at a rate of 1×10^{-9} mol s^{-1}. An unknown gas at the same temperature and pressure is found to effuse through the same opening at a rate of 3.78×10^{-10} mol s^{-1}. What is the molecular mass of the unknown gas?

A) 4 g mol^{-1} B) 14 g mol^{-1} C) 18 g mol^{-1} D) 28 g mol^{-1} E) 40 g mol^{-1}

14. Aluminum metal crystallizes in a face-centered cubic structure. What is the relationship between the radius of an Al atom (r) and the length of an edge of the unit cell (E)?

A) $r = E/2$

B) $r = E/\sqrt{8}$

C) $r = \left(\sqrt{3}/4\right)E$

D) $r = 2E$

E) $r = 4E$

15. Based on the phase diagram shown below, which of the following statements are correct?

I.   Sublimation occurs at a point in the transformation 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. ΔH_{vap} can be measured at point B.

IV. Molecules at point D have a greater average kinetic energy than those at point F.

V.   The temperature at point E is called the critical temperature of the compound.
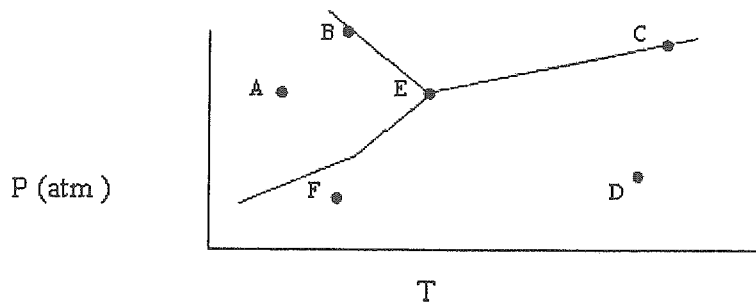
A) II, V

B) I, III, IV

C) I, II, III

D) II, IV, V

E) I, II, IV

16. A mixture of solid NaCl and $CaCl_2$ contains 10.0 g of NaCl, and an unknown amount of $CaCl_2$. When the entire mixture is dissolved in 1.00 kg of water, the boiling point changes by 0.25 °C. What mass of $CaCl_2$ was in the original mixture? K_b for water is 0.512 K·kg·mol^{-1}.

A) 5.4 g   B) 8.1 g   C) 35.2 g   D) 21.6 g   E) 17.6 g

17. Acetone (mw = 58.08, $P^*_{25°C}$=232 mmHg) and butanone (mw = 72.11, $P^*_{25°C}$=100 mmHg) have the indicated molar masses and vapor pressures. A container holds 1.00 kg of butanone. How much acetone must be added to the butanone to elevate the total vapor pressure over the mixture to 125 mmHg at 25°C?

A) 5.313 kg   B) 290 g   C) 188 g   D) 288 g   E) 94 g

18. The constant pressure heat capacity (c_p) generally increases with
   A)   the mass of the molecule
   B)   the internal degrees of freedom in th molecule
   C)   the number of atoms in the molecule
   D)   b and c
   E)   a and c

19. Which statement is true of a process in which 1 mol of a gas is expanded from state A to state B?
   A) When the gas expands from state A to state B, the surroundings are doing work on the system.
   B) The amount of work done in the process must be the same, regardless of the path.
   C) It is not possible to have more than one path for a change of state.
   D) The final volume of the gas will depend on the path taken.
   E) The amount of heat released in the process will depend on the path taken.

20. Which of the following coordination compounds will form a precipitate when treated with an aqueous solution of $AgNO_3$?
   A) $[Cr(NH_3)_3Cl_3]$
   B) $[Cr(NH_3)_6]Cl_3$
   C) $[Cr(NH_3)Cl]NO_3$
   D) $Na_3[Cr(CN)_6]$
   E) $Na_3[CrCl_6]$

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21. Which of the following statements about the CO_3^{2-} ion is *false*?
   A) The orbitals on the carbon atom are sp^2 hybridized.
   B) The ion is expected to be diamagnetic.
   C) One C–O bond is shorter than the others.
   D) The ion has a total of 24 electrons.
   E) It has a planar molecular geometry.

22. Solid KF has a lattice energy of -804 kJ/mol and a heat of solution (in water) of -15 kJ/mol. RbF has a lattice energy of -768 kJ/mol and a heat of solution (in water) of -24 kJ/mol. Which salt forms stronger attractions with water?
   A) KF, because it has a more exothermic lattice energy
   B) RbF, because it has a less exothermic lattice energy
   C) KF, because it has a more negative heat of hydration
   D) RbF, because it has a more negative heat of hydration
   E) They form equally strong attractions with water, because they both have negative heats of mixing.

23. Calculate the total number of unpaired electrons in the following complex ions:
   $[Zn(H_2O)_6]^{2+}$, $[NiCN_4]^{2-}$ (square planar), $[Co(NH_3)_6]^{3+}$ (strong field).
   A) 0   B) 1   C) 2   D) 3   E) 4

24. According to the VSEPR model, the electron pairs around NH_3 and those around CH_4 are arranged
   A) differently, because in each case there are a different number of atoms around the central atom.
   B) differently, because in each case there are a different number of electron pairs around the central atom.
   C) the same, because both nitrogen and carbon are in the second period.
   D) the same, because in each case there are the same number of electron pairs around the central atom.
   E) differently or the same, depending on the conditions leading to maximum repulsion.

25. For the reaction below, $K_p = 1.16$ at 700.°C.
   $$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$
   If a 24.6-g sample of $CaCO_3$ is put into a 14.2-L container and heated to 700.°C, what percent of the $CaCO_3$ will react to reach equilibrium?
   A) 36.9%   B) 83.9%   C) 20.6%   D) 100%   E) 67.0%

26. Calculate [H^+] in a 0.40 M solution of NaH_2PO_4. (For H_3PO_4, $K_{a1} = 7.5 \times 10^{-3}$, $K_{a2} = 6.2 \times 10^{-8}$, $K_{a3} = 4.8 \times 10^{-13}$)

A) $2.2 \times 10^{-5} M$ B) $1.6 \times 10^{-4} M$ C) $0.40 M$ D) $2.5 \times 10^{-4} M$ E) $3.9 \times 10^{-11} M$

27. Silver acetate ($AgC_2H_3O_2$) is a sparingly soluble salt with $K_{sp} = 1.9 \times 10^{-3}$. Consider a saturated solution in equilibrium with the solid salt. Compare the effects on the solubility of adding to the solution either the acid HNO_3 or the base NH_3.

A) Either substance would decrease the solubility.

B) NH_3 would increase the solubility, but HNO_3 would decrease it.

C) NH_3 would increase the solubility, but HNO_3 would have virtually no effect.

D) Either substance would increase the solubility.

E) NH_3 would decrease the solubility, but HNO_3 would increase it.

28. The reduction potentials for Au^{3+} and Ni^{2+} are as follows:

$$Au^{3+} + 3e^- \rightarrow Au \qquad E° = +1.50 \text{ V}$$
$$Ni^{2+} + 2e^- \rightarrow Ni \qquad E° = -0.23 \text{ V}$$

Calculate $\Delta G°$ (at 25°C) for the reaction

$$2Au^{3+} + 3Ni \rightarrow 3Ni^{2+} + 2Au$$

A) -5.00×10^2 kJ

B) $+5.00 \times 10^2$ kJ

C) -2140 kJ

D) $+1.00 \times 10^3$ kJ

E) -1.00×10^3 kJ

29. Which statement is true of a process in which 1 mol of a gas is expanded from state A to state B?

A) When the gas expands from state A to state B, the surroundings are doing work on the system.

B) he amount of work done in the process must be the same, regardless of the path.

C) It is not possible to have more than one path for a change of state.

D) The final volume of the gas will depend on the path taken.

E) The amount of heat released in the process will depend on the path taken.

30. An ethyl group ($CH_3CH_2^-$) that is attached to a substituent that does not contain a hydrogen atom appears as what in a NMR spectrum?

A) a doublet and a triplet with relative intensities of 2 and 3, respectively

B) a doublet and a triplet with relative intensities of 3 and 2, respectively

C) a triplet and a quartet with relative intensities of 2 and 3, respectively

D) a triplet and a quartet with relative intensities of 3 and 2, respectively

E) none of these 　　注意：背面有試題

31. Which base-pair is most stable in Wason-Crick DNA Structure?

(A)　(B)　(C)

(D)　(E)
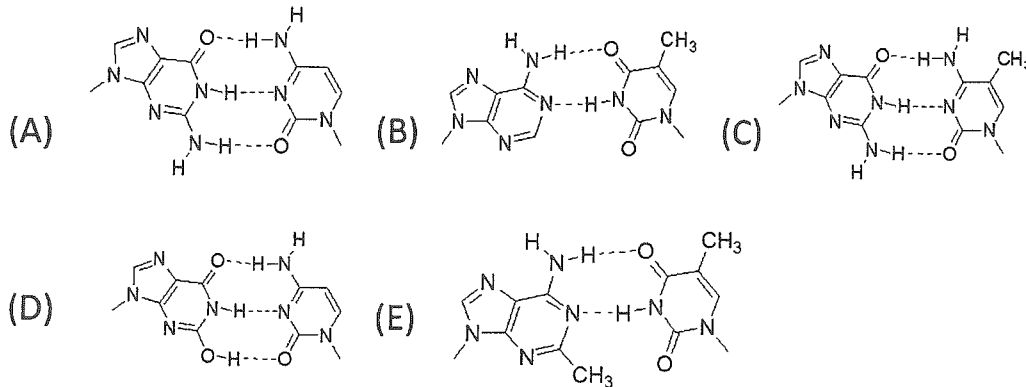
32. The following is a(n) _____ disaccharide with a(n) _____ glycosidic bond.
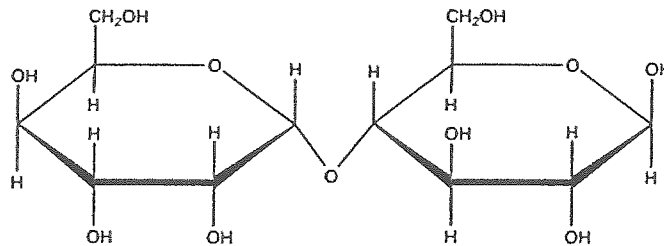
A) α; β(1→4)　B) α; β(1→1)　C) β; α(1→4)　D) β; α(1→1)
E) β; β(1→4)

33. If the following mixture of proteins was applied to a size-exclusion chromatography column, what would be the order of elution?

Proteins with molecular weights: myoglobin (17.7 kDa), hemoglobin (64.5 kDa), lysozyme (14.3 kDa) and triose phosphate isomerase (57.4 kDa)

A) lysozyme, myoglobin, triose phosphate isomerase, hemoglobin
B) triose phosphate isomerase, hemoglobin, lysozyme, myoglobin
C) hemoglobin, myoglobin, lysozyme, triose phosphate isomerase
D) hemoglobin, triose phosphate isomerase, myoglobin, lysozyme,
E) cannot be determined

34. What is the net charge of the pentapeptide Ala-Cys-Ser-Glu-Asn at pH 7?
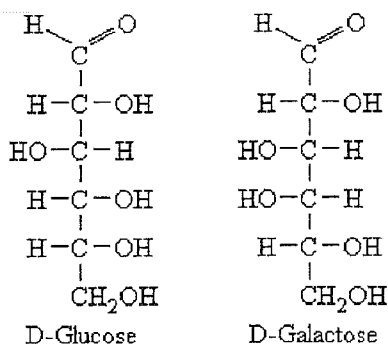A) -2 B) -3 C) 0 D) +1 E) +2

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35. The pKa's of arginine's α-Carboxyl group, α-Amino group and side chain are 1.8, 9.0 and 12.5, respectively. Calculate the isoelectric point.
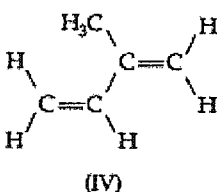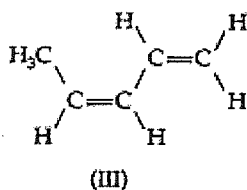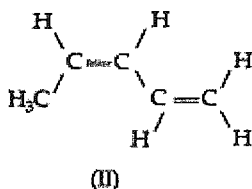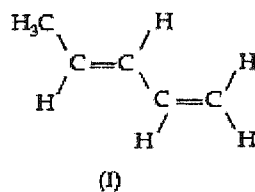
    A) 7.8 B) 7.2 C) 10.8 D) 5.4 E) 10.0

36. The Fischer projections of linear D-glucose and D-galactose are shown below. These two molecules are _____ .

D-Glucose　　D-Galactose

    A) epimers　　B) enantiomers　　C) anomers　　D) structural (constitutional) isomers

    E) same compound

37. Consider the following four compounds:

(I)　　(II)

(III)　　(IV)

Which of these compounds would have the same physical properties (melting point, boiling point, density, and so on)?

A)　I and II　　B)　I and III　　C) II and III　　D) III and IV　　E) I and IV

38. Radioactive elements decay via first-order kinetics. Consider a certain type of nucleus that has a rate constant of $1.6 \times 10^{-2}\,h^{-1}$. A sample contains 7.9×10^8 radioactive nuclides. Calculate the time required for 63% of the nuclides to decompose.

    A)2.9×10^1 h　　B)2.7×10^1 h　　C)1.3×10^1 h　　D)6.2×10^1 h　　E)1.3×10^{-1} h

39. Consider the following complexes:
    I. $Pt(NH_3)_2Cl_2$　　　(square planar)
    II. $Rh(en)_3^{2+}$　　　　(en = $H_2N-CH_2-CH_2-NH_2$ and is bidentate)
    III. $CoCl_4^{2-}$　　　　　(tetrahedral)
    Which can exhibit *cis-trans* isomerism?
    A)I　　B)II　　C)III　　D)I, II　　E)I, II, III

40. Thyroxine, an important hormone that controls the rate of metabolism in the body, can be isolated from the thyroid gland. If 0.455 g of thyroxine is dissolved in 10.0g of benzene, the freezing point of the solution is 5.144°C. Pure benzene freezes at 5.444°C and has a value for the molal freezing-point-depression constant of K_f of 5.12°C/*m*. What is the molar mass of thyroxine?
    A) 777,000 g/mol　　B) 777 g/mol　　C) 2330 g/mol　　D) 285 g/mol
    E) 3760 g/mol