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There are 69 questions on this exam. It is closed note/book. One 8.5 x 11 handwritten crib sheet (two-sided) is permitted.
Please turn off your cell phone. Use a #2 pencil.

Calculators are permitted. Computers, PDAs, and other electronic devices with a keyboard are not. Cell phones may not be used as calculators.

Complete the Scantron card. Identify your version and your section. Bubble in your student ID#. Scantron errors are punishable by point deductions.

A total of three hours is allotted for the exam. Answer every question. There is no penalty for guessing.

Circle your answers on the exam form, and bubble them in on the Scantron.

Circle Your Section

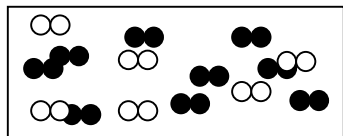
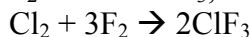
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Chapter 1.

1. Given the following pictorial representation for the chemical reaction of Cl_2 and F_2 to form ClF_3 , answer the following question.



●● = 2 moles of F_2
 ○○ = 2 moles of Cl_2

What is the theoretical yield of ClF_3 ?

- A. 12 mol
 B. 2.7 mol
 C. 7.3 mol
 D. 4.3 mol
 E. 6.0 mol

Answer A: This is a limiting reagent problem. You have 18 mol F_2 and 12 mol Cl_2 . 6 mol of Cl_2 will react with 18 mol of F_2 . So F_2 is limiting. 18 mol F_2 gives 12 mol ClF_3

2. What are the spectator ions in the equation below.
 $\text{NH}_4\text{Cl}(\text{aq}) + \text{AgNO}_3(\text{aq}) \rightarrow \text{AgCl}(\text{s}) + \text{NH}_4\text{NO}_3(\text{aq})$
- A. NH_4^+ and NO_3^-
 B. Ag^+ and NO_3^-
 C. NH_4^+ and Cl^-
 D. Ag^+ and Cl^-
 E. NH_4^+ and Ag^+

Answer A

Spectator ions stay in the aqueous phase on both sides of the rxn.

3. What is the correct oxidation state of the nitrogen in $[\text{ONO}_2]^-$?
- A. -7
 B. +5
 C. -5
 D. +4
 E. -4

Answer B:

Assume O is -2. The molecule has net charge of -1. So $-1 = 3(-2) + \text{OxSt}^{\text{N}}$
 $\text{OxSt}^{\text{N}} = +5$

4. Indium has atomic number 49 and atomic mass 114.8 g. Naturally occurring indium contains a mixture of indium-112 and indium-115, respectively, in an atomic ratio of approximately

- | | | |
|----|------------|------------|
| | Indium-112 | Indium-115 |
| A. | 6 | 94 |

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- | | | |
|----|----|----|
| B. | 25 | 75 |
| C. | 50 | 50 |
| D. | 75 | 25 |
| E. | 94 | 6 |

Answer A:

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5. Which of the following statements is **incorrect**?
- A. Ionic bonding results from the transfer of electrons from one atom to another.
 - B. Dipole moments result from the unequal distribution of electrons in a molecule.
 - C. Linear molecules cannot have a net dipole moment.
 - D. The electrons in a polar bond are found nearer to the more electronegative element.
 - E. A molecule with very polar bonds can be nonpolar.

Answer C.

6. Which of the following atoms has the greatest electronegativity?
- A. Carbon (C)
 - B. Magnesium (Mg)
 - C. Chromium (Cr)
 - D. Chlorine (Cl)
 - E. Oxygen (O)

Answer D:

7. What is the molecular geometry of H_2O ?
- A. Seesaw
 - B. Bent
 - C. Trigonal Planar
 - D. Trigonal Pyramidal
 - E. Trigonal Bipyramidal

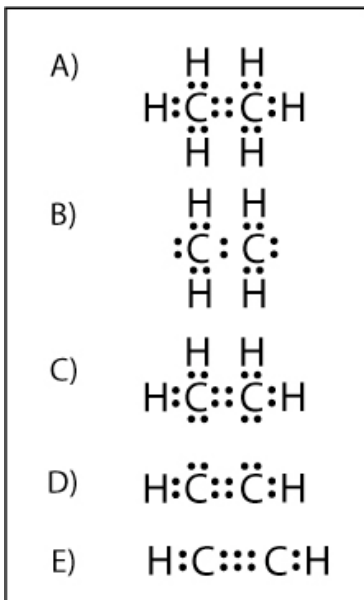
Answer B:

8. What is the molecular geometry of PCl_3 ?
- A. Seesaw
 - B. Bent
 - C. Trigonal Planar
 - D. Trigonal Pyramidal
 - E. Trigonal Bipyramidal

Answer D:

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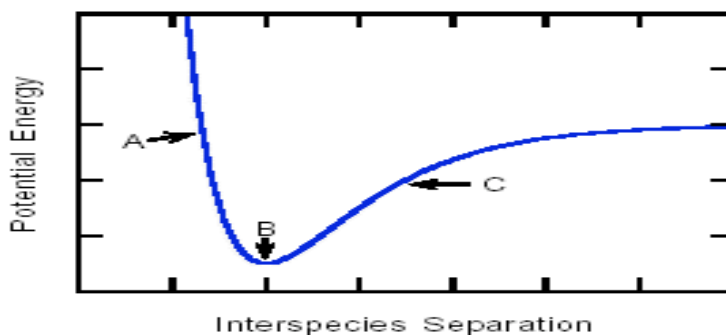
9. Which of these Lewis dot structures is correct?



- A. Structure A
 B. Structure B
 C. Structure C
 D. Structure D
 E. Structure E

Answer: E

10. Refer to the potential energy curve shown. This curve represents the dependence of the potential energy on separation of two atoms. In the portion of the curve labeled B:



- A. Attractive forces are greater than repulsive forces.
 B. Repulsive forces are greater than attractive forces.
 C. The combined kinetic energies of the atoms equals their potential energy.
 D. An increase in separation increases the potential energy.
 E. A decrease in separation increases the potential energy.

Answer D:

Answer E: two correct answers.

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11. Given the following combustion reaction, calculate the theoretical yield of carbon dioxide (CO₂) using the data in the table. Select the BEST answer from the choices provided.

	C ₂ H ₅ OH	+	3O ₂	→	2CO ₂ (g)	+	3H ₂ O (g)
Molecular Weight	46 g/mol		32 g/mol		44 g/mol		18 g/mol
Amount Reacted	2.5 g		1.01 g				

- A. 4.7 grams of CO₂
 B. 0.90 grams of CO₂
 C. 2.3 grams of CO₂
 D. 1.4 grams of CO₂
 E. 3.1 grams of CO₂

Answer B:

C₂H₅OH: (2.5g)(46g/mol)⁻¹=0.054 mol will consume 3(0.054 mol) = 0.16 mol O₂

Available O₂: (1.01g)(32g/mol)⁻¹=0.032. Since 0.032 < 0.16, O₂ is limiting.

CO₂: (2/3)(0.032 mol)(44g/mol)=0.94 (the 2/3 comes from the stoic coeffs)

12. The atom with the electron configuration 1s²2s²2p⁶3s²3p⁵ is

- A. F
 B. S
 C. Se
 D. Cl
 E. P

Answer: D

13. Atoms having greatly differing electronegativities are expected to form:

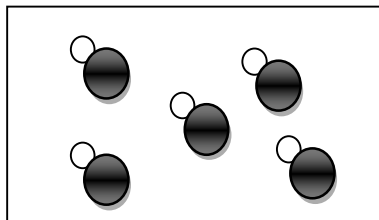
- A. no bonds
 B. polar covalent bonds
 C. nonpolar covalent bonds
 D. ionic bonds
 E. covalent bonds

Answer D:

14. Given a 1000-mL container of HCl as shown below, what is the molar concentration?



= one mole of HCl



- A. 50 M
 B. 5 M
 C. 2.5 M
 D. 25 M
 E. 10 M

Answer B: 5 mol/1L = 5 M

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15. Given the molecular formula for glucose, $C_6H_{12}O_6$, what is the empirical formula?
- $C_2H_4O_2$
 - $C_3H_6O_3$
 - $C_6H_{12}O_6$
 - CH_2O
 - $C_{12}H_{24}O_{12}$

Answer D:

16. Benzaldehyde (C_7H_6O) is a flavoring additive for lifesavers. If 3.93 nL are used in a lifesaver, how many MOLECULES of benzaldehyde are present if the density of benzaldehyde is 1.042 g/mL. Note: 1 nL = 10^{-9} L
- 2.3×10^{16} molecules
 - 2.3×10^{17} molecules
 - 4.6×10^{15} molecules
 - 6.9×10^{16} molecules
 - 7.7×10^{14} molecules

Answer A: $(3.93 \times 10^{-6} \text{ ml})(1.04 \text{ g/ml})(7 \times 12 + 6 + 16 \text{ g/mol})^{-1}(6.02 \times 10^{23} \text{ molecules/mol})$

17. For light with the following frequencies, which has the longest wavelength?
- $4.12 \times 10^5 \text{ s}^{-1}$
 - $8.50 \times 10^{20} \text{ s}^{-1}$
 - $9.12 \times 10^{12} \text{ s}^{-1}$
 - $3.20 \times 10^9 \text{ s}^{-1}$
 - $3.00 \times 10^{13} \text{ s}^{-1}$

Answer: A

smallest frequency => longest wavelength

18. Elements with _____ first ionization energies and _____ electron affinities generally form cations.
- low, very negative
 - high, positive or slightly negative
 - low, positive or slightly negative
 - high, very negative
 - no correct answer.

Answer C

19. Which of the following atoms or ions has 3 unpaired electrons?
- N
 - O
 - Ca
 - S^{2-}
 - Zn^{2+}

Answer A:

20. The shape of an atomic orbital is associated with
- the principal quantum number (n).
 - the angular momentum quantum number (l).

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- C. the magnetic quantum number (m_l).
- D. the spin quantum number (m_s).
- E. the magnetic and spin quantum numbers, together.

Answer B: for $l=0$ (s) the orbitals are spherical, for $l=1$ (p) the orbitals are orthogonal rabbit ears, etc.

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Chapter 2.

21. (assessment Exam 2) Dalton hypothesized that the total pressure of a mixture of gases equals the sum of the partial pressures of the individual gases. Initially a vessel is charged with a pressure of $O_2 = 1$ atm and pressure of $N_2 = 2$ atm. Assuming ideal gas behavior and no change in temperature or volume, if exactly one half of the N_2 (g) is removed, which result is consistent with Dalton's hypothesis?
- A. the final mole fraction of oxygen is 0.25
 - B. the final mole fraction of oxygen is 0.5
 - C. the final mole fraction of nitrogen is 0.25
 - D. the final mole fraction of nitrogen is 0.75
 - E. none of these are correct.

Answer B

22. What concentration of HF ($K_a = 7.2 \times 10^{-4}$) has the same pH as that of 0.044 M HCl?
- A. 0.37 M
 - B. 2.7 M
 - C. 0.044 M
 - D. 3.2×10^{-6} M
 - E. 1.6×10^{-2} M

Answer B**This requires an ICE diagram**

23. (assessment exam 2) What is the formal charge on each atom of the carbon monoxide ($C \equiv O$) molecule?
- A. C (-1), O (+1)
 - B. C (+1), O (-1)
 - C. C (0), O (0)
 - D. C (-1/2), O (+1/2)
 - E. None of these

Answer A

24. What is the molality of a solution of 39.6 g of ethanol (CH_3CH_2OH) in 442 mL of water? The density of water is 1 g/mL.
- A. 1.94 m
 - B. 89.6 m
 - C. 0.0350 m
 - D. 1.78 m
 - E. 0.0338 m

Answer A

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25. What is $[H^+]$ in an aqueous solution with a pH of 9.097?

- A. $2 \cdot 10^{-8} M$
- B. $1 \cdot 10^{-1} M$
- C. $9.1 M$
- D. $8.0 \cdot 10^{-10} M$
- E. $4.9 M$

Answer D

$$[H^+] = 10^{-9.097} = 8.0 \times 10^{-10}$$

26. For the reaction: $aA(g) + bB(g) \rightleftharpoons cC(g) + \text{heat}$
with $a = 1$, $b=1$ and $c=1$. An increase in total pressure (at const T)

- A. increases the number of moles of A
- B. decreases the number of moles of A
- C. does not change the number of moles of A

Answer B

There are more molecules in the gas phase on the LH side, so increasing the P drives it to the right

27. For the reaction: $aA(g) + bB(g) \rightleftharpoons cC(g) + \text{heat}$
with $a = 1$, $b=1$ and $c=3$. An increase in total pressure (at const T)

- A. increases the equilibrium constant
- B. decreases the equilibrium constant
- C. does not change the equilibrium constant

Answer C

Changing P will not change K

28. Which one of the following is the strongest intermolecular interactions in H_2O (liq)?

- A. London dispersion interactions
- B. dipole-induced dipole interactions
- C. hydrogen bonds
- D. polar covalent bonds
- E. ionic bonds

Answer C

29. For the reaction: $aA(g) + bB(g) \rightleftharpoons cC(g) + \text{heat}$
with $a = 1$, $b=1$ and $c=3$. An increase in T

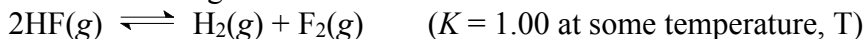
- A. Increases the number of moles of A
- B. Decreases the number of moles of A
- C. Does not change the number of moles of A

Answer A

For a reaction that evolves heat, adding heat drives it to the left (and changes K).

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30. Consider the following reaction:



Given 1.0 mol of HF(g), 0.5 mol of H₂(g), and 1.0 mol of F₂(g) are mixed in a 1.00-L flask, determine the direction required to achieve equilibrium.

- A. the system is at equilibrium.
- B. the system shifts to the left to reach equilibrium.
- C. the system shifts to the right to reach equilibrium.
- D. the direction of the driving force cannot be determined by the information provided.

Answer C

31. For the reaction $2\text{NCl}_3(\text{g}) \rightleftharpoons \text{N}_2(\text{g}) + 3\text{Cl}_2(\text{g})$, the equilibrium pressures are

$$P(\text{NCl}_3) = 0.10 \text{ atm}$$

$$P(\text{N}_2) = 2.3 \text{ atm}$$

$$P(\text{Cl}_2) = 0.056 \text{ atm}$$

Determine K_p for this reaction.

- A. 1.3
- B. 1.9
- C. 0.040
- D. 0.27
- E. none of these

Answer: C

$$P(\text{N}_2)P(\text{Cl}_2)^3/P(\text{NCl}_3)^2 = (2.3)(0.056)^3/(0.10)^2 = 4.0 \times 10^{-2}$$

32. Air is 79% N₂ and 21% O₂ weight to volume. Calculate the density of air at 1.0 atm, 25°C.

- A. 14.1 g/L
- B. 2.46 g/L
- C. 0.590 g/L
- D. 1.18 g/L
- E. 1.29 g/L

Answer D

% is weight to volume

for 1 g of air

$$\text{N}_2: (0.79\text{g}) (28\text{g/mol})^{-1} = n_{\text{N}_2} = 0.0282 \text{ mol}$$

$$\text{O}_2: (0.21\text{g}) (32\text{g/mol})^{-1} = n_{\text{O}_2} = 0.0066 \text{ mol}$$

$$V_{\text{TOT}} = (n_{\text{N}_2} + n_{\text{O}_2})RT/P = (0.0348 \text{ mol}) (0.082 \text{ L atm mol}^{-1} \text{ K}^{-1})(298 \text{ K})(1 \text{ atm})^{-1} \\ = 0.850 \text{ L}$$

$$1\text{g}/0.850 \text{ L} = 1.18 \text{ g/L}$$

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33. Which of the following does not represent a conjugate acid-base pair?
- A. $\text{C}_5\text{H}_5\text{NH}^+$ and $\text{C}_5\text{H}_5\text{N}$
 - B. HCN and NH_3
 - C. HF and F^-
 - D. H_3O^+ and H_2O

Answer B

34. What is the equilibrium expression for the reaction
- $$2\text{SO}_2(\text{aq}) + \text{O}_2(\text{aq}) \rightleftharpoons 2\text{SO}_3(\text{aq}) ?$$

- A. $\frac{[\text{SO}_3]}{[\text{SO}_2][\text{O}_2]}$
- B. $\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]}$
- C. $\frac{[\text{SO}_3]^2}{[\text{SO}_2]^2[\text{O}_2]^2}$
- D. $\frac{[\text{SO}_2]^2[\text{O}_2]}{[\text{SO}_3]^2}$

Answer B

35. A cylinder is fitted with a movable piston containing an ideal gas. The pressure inside the cylinder is P_i and the volume is V_i . What is the new pressure in the system when the piston decreases the volume of the cylinder by half, at constant T?
- A. $2V_iP_i$
 - B. $(1/4)P_i$
 - C. P_i^2
 - D. $2P_i$
 - E. $(1/2)P_i$

Answer D

36. Consider two samples of helium in the gas phase in separate containers of the same volume and pressure. Sample 1 has an absolute temperature four times that of Sample 2. Calculate the molar ratio n_1/n_2 .
- A. 1:2
 - B. 4:1
 - C. 1:1
 - D. 1:4
 - E. 2:1

Answer D

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37. Which of the following has the lowest boiling point?

- A. NH₃
- B. N₂
- C. CH₄
- D. He
- E. Ne

Answer D

38. To calculate the freezing point of an ideal dilute solution of a single, non-dissociating solute, the minimum information one must know is

- I. the molality (of the solute).
 - II. the freezing-point-depression constant of the solvent
 - III. the freezing point of the pure solvent.
 - IV. the molecular weight of the solute.
 - V. the weight of the solvent.
- A. II, III, IV
 - B. I only
 - C. II only
 - D. II, III, V
 - E. I, II, III only

Answer E

39. Which of the following statements is universally TRUE?

- A. A catalyst will change an equilibrium constant.
- B. At equilibrium, all opposing reactions proceed at identical rates.
- C. The melting of ice releases heat to the surroundings.
- D. At equilibrium, the concentrations of the products are equal to those of reactants.
- E. At equilibrium, the concentration of the products is greater than that of the reactants.

Answer B

40. (assessment question) In 1884 Henri Le Châtelier hypothesized that a system in equilibrium that is subjected to a stress reacts in a way that tends to counteract the stress. In testing this hypothesis through experimentation, what would NOT be the expected observations for the following system at equilibrium in a closed vessel.



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i.e., which of the following is FALSE?

- A. Adding PCl_3 (g) increases the partial pressure of PCl_5 . **True**
- B. Adding Cl_2 (g) decreases the partial pressure of PCl_3 . **True**
- C. Removing PCl_5 decreases the partial pressure of PCl_3 . **True**
- D. Decreasing the volume at constant temperature leads to a net production of PCl_5 .
True
- E. Decreasing the volume at constant temperature leads to a net production of PCl_3 .
False

Answer E

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Chapter 3.

41. The heat gained by the system from the surroundings in a process carried out at constant pressure is

- A. w
- B. $-\Delta H$
- C. ΔH
- D. ΔE
- E. ΔS

Answer: C

42. Which one of the following statements is **NOT** true concerning the equation below?



- A. The complete reaction of 1.0 mole of N_2 produces 460 kJ of heat.
- B. The complete reaction of 1.0 mole of H_2 consumes 153 kJ of heat.
- C. The production of 1.0 mole of ammonia is accompanied by the production of 230 kJ of heat.
- D. The complete reaction of 1.38 mole of hydrogen requires 0.46 mole of nitrogen.
- E. All of these are true statements.

Answer: B, the forward reaction produces heat

43. The First Law of Thermodynamics states that

- A. work and heat are interconvertable
- B. energy is conserved
- C. energy cannot be created or destroyed
- D. none of the above
- E. all of the above (a-c)

Answer: E

44. Which of the following is not a state function?

- A. q
- B. E
- C. H
- D. G
- E. All of these are state functions.

Answer: a

45. Which of the following processes has $\Delta H > 0$?

- A. combustion of a hydrocarbon (gives off heat, $\Delta H_{\text{combust}} < 0$)
- B. dilution of concentrated hydrochloric acid with water (gives off heat, $\Delta H < 0$)
- C. vaporization of water (absorbs heat, makes you, the surroundings, cold $\Delta H > 0$)
- D. freezing of liquid N_2 (gives off heat, $\Delta H < 0$)
- E. all have $\Delta H > 0$

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Answer: c

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46. What quantity of NaOH(s) must be added to 1.00 L of 0.200 M HCl to achieve a pH of 12.0? (assume constant volume.)

- A. 0.20 mole
- B. 0.42 mole
- C. 0.21 mole
- D. 0.01 mole
- E. none of these

Answer: c

0.2 moles are required to bring the pH to 7 (neutralize the HCl).

0.01 moles are required to bring the pH from 7 to 12.

47. Calculate the $[H^+]$ in a solution that is 0.10 M in NaF and 0.20 M in HF ($K_a = 7.2 \times 10^{-4}$).

- A. $0.20 \times 10^{-1} M$
- B. $7.0 \times 10^{-4} M$
- C. $1.4 \times 10^{-3} M$
- D. $3.6 \times 10^{-4} M$
- E. none of these

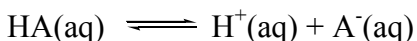
Answer: c

I	$[HF]$ 2×10^{-1}	$[F^-]$ 1×10^{-1}	$[H^+]$ 10^{-7}
C	-x	x	x
E	$(2 \times 10^{-1}) - x$	$(1 \times 10^{-1}) + x$	$10^{-7} + x$

Assume $10^{-1} \gg x \gg 10^{-7}$

$$K_a = [H^+][F^-] = (10^{-1})(x)/(2 \times 10^{-1}) \quad x = 7.2 \times 10^{-4}(2 \times 10^{-1})(10^{-1}) = 1.4 \times 10^{-3}$$

48. Consider the solution buffered by the weak acid HA.



Which of the statements below is false?

A. Addition of NaCl(s) to produce $Na^+(aq)$ and $Cl^-(aq)$ will change the pH. **False: NaCl is not an acid or base, and there is no common ion.**

B. If the ratio of $[A^-]/[HA]$ is constant, the pH is constant. **True: $pH = pK_a + \log[A^-]/[HA]$**

C. The solution resists change in pH when acid or base is added. **True: that is the definition of a buffer.**

D. The buffering capacity is maximum when $pH = pK_a$. **True: $pH = pK_a + \log[A^-]/[HA]$ and the % change of $[A^-]/[HA]$ with change in $[A^-]$ is a minimum when $[A^-]/[HA] = 1$.**

E. $pH = pK_a + \log[A^-]/[HA]$. **True: That is the Henderson-Hasselbalch equation.**

Answer: a

Given the following enthalpies of formation:

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Species	ΔH_f° (kJ mol ⁻¹)
glucose [C ₆ H ₁₂ O ₆ (s)]	-1274
CO ₂ (g)	-393
H ₂ O(l)	-286

49. What is the standard enthalpy of combustion of glucose to form carbon dioxide and liquid water.

- A. -1953 kJ mol⁻¹
- B. -2800 kJ mol⁻¹
- C. -595 kJ mol⁻¹
- D. 595 kJ mol⁻¹
- E. none of these

Answer: B

A perfect gas is very slowly compressed from 45 L to 18 L at a constant external pressure of 5.0 atm. During this process 9.8 kJ of energy is released as heat.

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50. The work w for this process is

- A. -9.82 L atm
- B. 9.82 L atm
- C. 135 L atm
- D. -135 L atm
- E. 270 kJ

Answer: C

$$w = -P\Delta V = -5(18-45) = 135 \text{ L atm}$$

51. The heat q for this process is

- A. 135 kJ
- B. -135 kJ
- C. 9.8 kJ
- D. -9.8 kJ
- E. 270 kJ

Answer: D

If q is released to the surroundings, $q_{\text{sys}} < 0$.52. In any process, $\Delta E_{\text{univ}} =$

- A. ΔE_{sys}
- B. ΔE_{surr}
- C. $-\Delta E_{\text{sys}}$
- D. 0
- E. $-\Delta E_{\text{surr}}$

Answer: D

53. Given the following ΔH_f° values:

$\text{SiH}_4(\text{g})$	34.3 kJ mol^{-1}
$\text{SiO}_2(\text{s})$	$-910.9 \text{ kJ mol}^{-1}$
$\text{H}_2\text{O}(\text{l})$	$-285.8 \text{ kJ mol}^{-1}$
$\text{O}_2(\text{g})$	0.0 kJ mol^{-1}

Also,

$$\text{H}_2\text{O} \quad \Delta H_{\text{vap}} = 44.0 \text{ kJ mol}^{-1}.$$

Calculate ΔH_r° for $\text{SiH}_4(\text{g}) + 2\text{O}_2(\text{g}) \rightleftharpoons \text{SiO}_2(\text{s}) + 2\text{H}_2\text{O}(\text{s})$.

- A. $-1517 \text{ kJ mol}^{-1}$
- B. $-1429 \text{ kJ mol}^{-1}$
- C. $-1187 \text{ kJ mol}^{-1}$
- D. This cannot be determined without additional information.
- E. none of these

Answer: d, you need to know ΔH_{fusion} for H_2O .

54. The second law of thermodynamics states that

- A. energy is conserved in spontaneous processes.

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- B. the heat content of the universe increases during a spontaneous process.
- C. the entropy of the universe increases during a spontaneous process.
- D. the entropy of a perfect crystal is zero at absolute zero.
- E. work and heat are interconvertible.

Answer: C

55. For the vaporization of a liquid at its boiling point T_b , the change in entropy and the change in enthalpy are related by

- A. $\Delta S_{\text{vap}} = \Delta H_{\text{vap}}/T_b$
- B. $\Delta S_{\text{vap}} = T_b\Delta H_{\text{vap}}$
- C. $\Delta S_{\text{vap}} = T_b/\Delta H_{\text{vap}}$
- D. $T_b = \Delta H_{\text{vap}}\Delta S_{\text{vap}}$
- E. There is no general relation covering these vaporization quantities.

Answer: A, at the boiling point $0 = \Delta G = \Delta H_{\text{vap}} - T_b\Delta S_{\text{vap}}$

56. If ΔS_{univ} is positive for a process, the process is _____, if ΔS_{univ} for a process is negative, the process is _____, and if the ΔS_{univ} for a process is zero, the process is _____.

- A. at equilibrium, spontaneous, nonspontaneous
- B. nonspontaneous, spontaneous, at equilibrium
- C. spontaneous, at equilibrium, nonspontaneous
- D. spontaneous, nonspontaneous, at equilibrium
- E. none of these

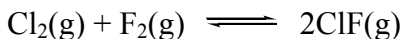
Answer: D

57. A process can proceed spontaneously in the forward direction at low temperatures and in the reverse direction at high temperatures if

- A. ΔH is positive and ΔS is negative.
- B. ΔH is negative and ΔS is positive.
- C. both ΔH and ΔS are positive
- D. both ΔH and ΔS are negative.
- E. This cannot be answered in such a general way.

Answer: D, $\Delta G = \Delta H - T\Delta S$. At low T the ΔH term dominates and $\Delta H < 0$ will drive reaction forward. At high T, $T\Delta S$ term dominates and $\Delta S < 0$ will drive the reaction in reverse.

58. For the reaction below, $K = 8.6 \times 10^1$ at $T = 298 \text{ K}$.



What is $\Delta G^\circ_{\text{rxn}}$?

- A. -11 kJ
- B. 26 kJ
- C. 0 kJ
- D. -26 kJ

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E. cannot be determined

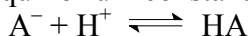
$$\Delta G_{\text{rxn}}^{\circ} = -RT \ln K = -(8.31 \text{ J K}^{-1} \text{ mol}^{-1})(298 \text{ K})[\ln(86)] = -11 \text{ kJ}$$

59. Consider an isolated system consisting of two bricks that are identical in all ways except that initially one brick is hot (brick^{hot}) and the other brick is cold (brick^{cold}). In the final state the two bricks have reached the same temperature. For this equilibration process:

- A. $\Delta E(\text{brick}^{\text{hot}}) < 0$
 $\Delta E(\text{brick}^{\text{cold}}) > 0$
 $\Delta E(\text{sys}) < 0$
- B. $\Delta S(\text{brick}^{\text{hot}}) < 0$
 $\Delta S(\text{brick}^{\text{cold}}) > 0$
 $\Delta S(\text{sys}) = 0$
- C. $\Delta E(\text{brick}^{\text{hot}}) < 0$
 $\Delta E(\text{brick}^{\text{cold}}) > 0$
 $\Delta E(\text{sys}) = 0$
- D. $\Delta E(\text{brick}^{\text{hot}}) = -\Delta E(\text{brick}^{\text{cold}}) = 0$
 $\Delta E(\text{sys}) = 0$
- E. $\Delta S(\text{brick}^{\text{hot}}) = -\Delta S(\text{brick}^{\text{cold}})$
 $\Delta S(\text{sys}) > 0$

Answer: C

60. The equilibrium constant for the reaction



Is called:

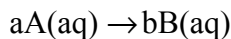
- A. K_a
- B. K_b
- C. $\frac{1}{K_a}$
- D. $\frac{K_w}{K_b}$
- E. $K_w K_a$

Answer: C

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Chapter 4.

61. For a reaction

the rate constant k is dependent on

- A. Concentration(s) of reactant(s).
- B. Concentration(s) of product(s).
- C. Temperature.
- D. Time from initiation (how long the reaction been running).
- E. Pressure

Answer: C (unless the activation enthalpy is zero). The concentration of reactants changes the rate, but not the rate constant.

62. The experimental rate law for the decomposition of nitrous oxide (N_2O) to N_2 and O_2 is: Rate = $k[N_2O]^2$. Several mechanisms are proposed:

A. $N_2O \rightarrow N_2 + O$ $N_2O + O \rightarrow N_2 + O_2$	B. $N_2O \rightarrow N + NO$ $N_2O + N + NO \rightarrow N_3 + O_2$ $2N_3 \rightarrow 3N_2$
C. $2N_2O \rightarrow N_4O_2$ $N_4O_2 \rightarrow 2N_2 + O_2$	D. $3N_2O \rightarrow N_6O_3$ $2N_6O_3 \rightarrow 6N_2 + 3 O_2$

Which of the mechanisms above is most likely to be correct?

- A. Mechanism A.
- B. Mechanism B.
- C. Mechanism C.
- D. Mechanism D.
- E. None of these mechanisms are consistent with the experimental rate law.

Answer: C

63. A highly spontaneous reaction, with a large forward driving force

- A. is necessarily a fast forward reaction.
- B. could be a slow forward reaction.
- C. is necessarily a fast reverse reaction.
- D. could be a fast reverse reaction.
- E. None of these are correct

Answer: B. It seems like many students had a hard time with this one. Please refer to Figure 10.2 in Zumdahl, which should have entropy_{uni} or free energy as the horizontal axis.

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64. The following data were obtained for the reaction of NO with O₂. Concentrations are in M and rates are in M s⁻¹.

[NO] ₀	[O ₂] ₀	Initial Rate
1 × 10 ¹⁸	1 × 10 ¹⁸	2.0 × 10 ¹⁶
2 × 10 ¹⁸	1 × 10 ¹⁸	8.0 × 10 ¹⁶
3 × 10 ¹⁸	1 × 10 ¹⁸	18.0 × 10 ¹⁶
1 × 10 ¹⁸	2 × 10 ¹⁸	4.0 × 10 ¹⁶
1 × 10 ¹⁸	3 × 10 ¹⁸	6.0 × 10 ¹⁶

Which of the following is the rate law for this reaction?

- A. Rate = $k[\text{NO}][\text{O}_2]$
- B. Rate = $k[\text{NO}][\text{O}_2]^2$
- C. Rate = $k[\text{NO}]^2[\text{O}_2]$
- D. Rate = $k[\text{NO}]^2$
- E. Rate = $k[\text{NO}]^2[\text{O}_2]^2$

Answer: C

65. The rate of a reaction can change with
- A. Temperature.
 - B. The addition of a catalyst or enzyme.
 - C. Reactant concentrations.
 - D. ALL of the above (a-c).
 - E. None of the above (a-c).

Answer: D

66. The rate of disappearance of ozone in the reaction $2\text{O}_3(\text{g}) \rightarrow 3\text{O}_2(\text{g})$ is $9.0 \times 10^{-3} \text{ atm s}^{-1}$. What is the rate of appearance of O₂ during this interval?

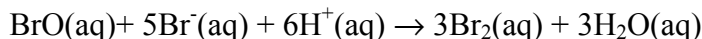
- A. $1.3 \times 10^{-2} \text{ atm s}^{-1}$
- B. $9.0 \times 10^{-3} \text{ atm s}^{-1}$
- C. $6.0 \times 10^{-3} \text{ atm s}^{-1}$
- D. $3.0 \times 10^{-5} \text{ atm s}^{-1}$
- E. $2.7 \times 10^{-5} \text{ atm s}^{-1}$

Answer: A

$$(3/2)9.0 \times 10^{-3} = 1.3 \times 10^{-2} \text{ atm/s}$$

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67. The balanced equation for the reaction of bromate with bromide to produce bromine (Br_2) in acidic solution is given by:



When $d[\text{Br}^-]/dt$ is $2.0 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$, what is $dt[\text{Br}_2]/dt$?

- A. $-1.2 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$
 B. $+1.2 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$
 C. $-3.3 \times 10^{-4} \text{ mol L}^{-1} \text{ s}^{-1}$
 D. $+3.3 \times 10^{-4} \text{ mol L}^{-1} \text{ s}^{-1}$
 E. $+6.0 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$

Answer A:

$(-3/5)(2.0 \times 10^{-3}) = -1.2 \times 10^{-3}$ Note the sign. If the rate is positive on one side of the equation it is negative on the other. If things are decreasing on one side they must be increasing on the other.

<p>68. I regret that chemistry is not my major. A) True B) False (hint: this is the wrong answer) Answer: A or B</p>	<p>69. This is exam version A. B. C. Answer: A or B or C</p>
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Constants:

$$1 \text{ mole} = 6.022 \times 10^{23} \text{ atoms}$$

$$1 \text{ mole} = 6.022 \times 10^{23} \text{ molecules}$$

$$1 \text{ mole} = 6.022 \times 10^{23} \text{ ions}$$

$$h = 6.626 \times 10^{-34} \text{ Js}$$

$$1 \text{ J (Joule)} = 1 \text{ kg} \frac{\text{m}^2}{\text{s}^2}$$

$$c = 3.0 \times 10^8 \text{ m/s}$$

$$\text{Mass of an Electron} = 9.10939 \times 10^{-31} \text{ kg}$$

$$\text{Mass of a Proton} = 1.67 \times 10^{-27} \text{ kg}$$

$$\text{Mass of a Neutron} = 1.67 \times 10^{-27} \text{ kg}$$

$$R = 0.0821 \frac{\text{Latm}}{\text{molK}}$$

$$R = 8.31 \frac{\text{J}}{\text{molK}}$$

$$V.P.(\text{H}_2\text{O}, 373\text{K}) = 760 \text{ torr}$$

Stoichiometry:

$$\text{Density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{Molarity} = M = \frac{\text{mole of solute}}{\text{L of solvent}}$$

$$n \text{ (number of moles)} = \frac{\text{mass}}{\text{Molar Mass}}$$

Quantum Mechanics

$$c = \lambda \nu$$

$$E = mc^2$$

$$\lambda = \frac{h}{p}$$

$$\hat{H}\psi = E\psi$$

$$\Delta x * m\Delta v \geq \frac{h}{4\pi}$$

$$\text{Maximum Occupancy} = 2n^2$$

Name _____ Section Number _____

Solubility Rules

1. All alkali metal salts are soluble.
2. All ammonium (NH_4^+) salts are soluble.
3. All chlorides, bromides, and iodides are soluble except those of Ag^+ , Hg_2^{2+} , and Pb^{2+} .
4. All nitrates, chlorates, and perchlorates are soluble.
5. All sulfates except those of Ca^{2+} , Sr^{2+} , Ba^{2+} , Pb^{2+} , Hg_2^{2+} , and Ag^+ .
6. All carbonates, chromates, oxalates, and phosphates are insoluble except those of the alkali metals and ammonium.
7. All hydroxides are insoluble except those of the alkali metals.

Bonding

$$\text{Formal Charge} = V - (L + 0.5 S)$$

V = Number of Valence Electrons

L = The Number of Lone Pair Electrons

S = The Number of Shared Electrons

Name _____ Section Number _____

Solutions

$$P = X_1 \cdot P^o$$

$$m = \text{molality} = \frac{\text{mol of solute}}{\text{kg of solvent}}$$

$$\Delta T_f = -m \cdot K_f$$

$$\Delta T_b = m \cdot K_b$$

$$X_1 = \text{mole fraction} = \frac{n_1}{n_{\text{total}}}$$

$$\Pi = MRT$$

Gas Laws

$$P_1 V_1 = P_2 V_2$$

$$V_1 T_2 = V_2 T_1$$

$$PV = nRT$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\text{Kelvin} = ^\circ\text{C} + 273.15$$

$$\left(P + a \frac{n^2}{V^2}\right)(V - nb) = nRT$$

$$P_{\text{total}} = P_1 + P_2 + \dots + P_n$$

$$KE(\text{mol}) = \frac{3}{2} RT \text{ (monoatomic)}$$

$$KE(\text{particle}) = \frac{1}{2} mu^2$$

Thermodynamics

$$\Delta G^o = -RT \ln K$$

$$E = q + w$$

$$w = -P_{\text{ext}} \Delta V$$

$$C_p = \frac{5}{2} R \text{ (monoatomic ideal gas)}$$

$$C_v = \frac{3}{2} R \text{ (monoatomic ideal gas)}$$

$$\Delta H = q_p \text{ (constant temperature)}$$

$$w_{\text{rev}} = -nRT \ln \left(\frac{V_2}{V_1} \right)$$

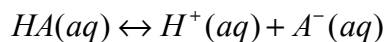
Acid-Base

$$pH = -\log [H^+]$$

$$pOH = -\log [OH^-]$$

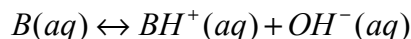
$$K_w = K_a K_b$$

$$pH + pOH = 14$$



$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$K_w = 1 \times 10^{-14} \text{ at } 25^\circ\text{C}$$



$$K_b = \frac{[BH^+][OH^-]}{[B]}$$

$$pKa = -\log K_a$$

$$pKw = 14 \text{ at } 25^\circ\text{C}$$

$$pH = pKa + \log \left(\frac{[\text{base}]}{[\text{acid}]} \right)$$

$$q = mC\Delta T$$

$$q_v = nC_v \Delta T$$

$$q_p = nC_p \Delta T$$

$$dS = \frac{dq}{T}$$

$$\Delta G = \Delta H - T\Delta S$$

$$\Delta G = -RT \ln K$$

$$T_c = \frac{\Delta H}{\Delta S}$$

$$C_{\text{water}} = 4.184 \frac{\text{J}}{\text{molK}}$$

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For $aA + bB \rightarrow cC$ Kinetics

$$\text{Rate} = -k[A]^a[B]^b$$

integrated rate law for $a=0, b=0$: $[A] = kt + [A]_0$ integrated rate law for $a=1, b=0$: $\ln [A] = -kt + \ln[A]_0$ integrated rate law for $a=2, b=0$: $[A]^{-1} = kt + \ln[A]_0$