Chem 1141
Fall 2014
Exam 3D

Name: KEY

Please write your full name, and which exam version (3D) you have on the scantron sheet.

Please ☑ check the box next to your correct section number.

Section #: ❒ 1. (Tuesday Lab, 4 – 6:50 pm) ❒ 2. (Thursday Lab, 4 – 6:50 pm)
❒ 3. (Monday Lab, 11 – 1:50 pm) ❒ 4. (Wednesday Lab, 11 –1:50pm)
❒ 5. (Wednesday Lab, 2 – 4:50 pm)

Multiple Choice:	______	**/30**
Q11:	______	**/10**
Q12:	______	**/10**
Q13:	______	**/10**
Q14:	______	**/10**
Q15:	______	**/10**
Q16:	______	**/10**
Q17:	______	**/10**
BONUS:	______	**/3**
TOTAL:	______	**/100**

Multiple Choice. [3 points each.] Record your answers to the multiple choice questions on the scantron sheet.

Q1. The amount of heat required to raise the temperature of **one gram** of a substance by 1°C is the sample's:

a) heat capacity b) internal energy c) enthalpy d) specific heat s

e) calorimetry

heat to raise entire sample by 1°C

$q = m \cdot s \cdot \Delta t$; 1g ; 1°C ; $q \sim s$

Q2. In the van der Waals equation, what does the term $\boldsymbol{a}$ account for?

a) The polarity of the gas particles b) The kinetic energy of the gas particles

c) The attractions between the gas particles d) The size of the gas particles

e) The diffusion of the gas particles

Q3. The overall reaction in a commercial heat pack can be represented as:

$$4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s) \qquad \Delta H^\circ_{rxn} = -1652 \text{ kJ/mol}$$

How much heat is released when 6.000 mol of $O_2(g)$ is reacted?

$$\frac{6.000 \text{ mol } O_2 \;|\; -1652 \text{ kJ}}{\;|\; 3 \text{ mol } O_2} = -3304 \text{ kJ}$$

released (lost by rxn)

a) 1652 kJ b) 826.0 kJ c) 3304 kJ d) 9910 kJ e) 275.3 kJ

Q4. Given the following thermochemical equation:

$$A(aq) + 2B(aq) \longrightarrow C(g) + D(s) \qquad ; \Delta H^\circ_{rxn} = +12.0 \text{ kJ/mol}$$

Then calculate ΔH°_{rxn} for:

$$2C(g) + 2D(s) \longrightarrow 2A(aq) + 4B(aq)$$

reversed $(\times -1)$ and doubled $(\times 2)$ → $\times(-1)\times(2) = -24.0 \text{ kJ/mol}$

a) +24.0 kJ/mol b) −24.0 kJ/mol c) +6.0 kJ/mol d) −6.0 kJ/mol

e) Not enough information to determine

Q5. Which substance(s) below **does not** have a heat of formation (ΔH_f°) equal to zero at 25°C and 1 atm?

a) $N_2(l)$ b) $Xe(g)$ c) $Na(s)$ d) $O_2(g)$ e) a and b

Q6. The set of quantum numbers that correctly describes an electron in a 3p orbital is:

a) $n = 3; l = 0; m_l = 0; m_s = 0$

b) $n = 3; l = 2; m_l = -2, -1, 0, +1, \text{or } +2; m_s = +½ \text{ or } -½$

c) $n = 3; l = 1; m_l = -1, 0, \text{or } +1; m_s = +½ \text{ or } -½$

d) $n = 4; l = 0; m_l = -1, 0, \text{or } +1; m_s = +½ \text{ or } -½$

e) none of the above

$n=3$ $l=1$

$m_l = -l, \ldots, 0, \ldots, +l$

$m_s = \pm ½$

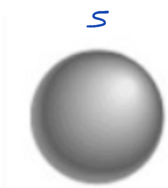
l	0	1	2	3
code	s	p	d	f

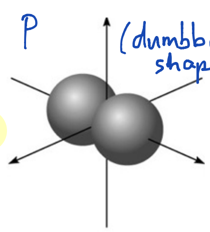
Q7. "No two electrons in an atom can have the same four quantum numbers" is a statement called:

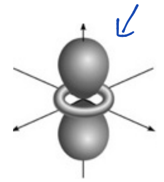
a) Pauli exclusion principle b) Bohr's equation c) Hund's rule

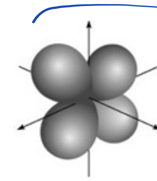
d) de Broglie's relation e) Dalton's atomic theory

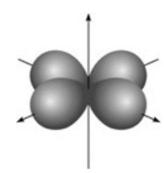
Q8. Which of the following corresponds to the shape of a p-orbital?

a)  s

b)  p (dumbbell shape)

c)  d_{z^2}

d)  d

e) 

Q9. Which color of visible light has the highest energy per photon?

a) Red b) Orange c) Yellow d) Green e) Blue

$E = \frac{hc}{\lambda}$, $E \propto \frac{1}{\lambda}$ $\boxed{\lambda\downarrow E\uparrow}$

Red Orange Yellow Green Blue Violet

$\lambda \sim 700$nm $\lambda\downarrow$ $\lambda \sim 400$nm

$E\uparrow$

Aufbau : [Ar] $4s^2 3d^4$
but... move $1e^-$ from $4s \rightarrow 3d$ to have stable $\frac{1}{2}$-filled 3d $\Rightarrow$ [Ar] $4s^1 3d^5$

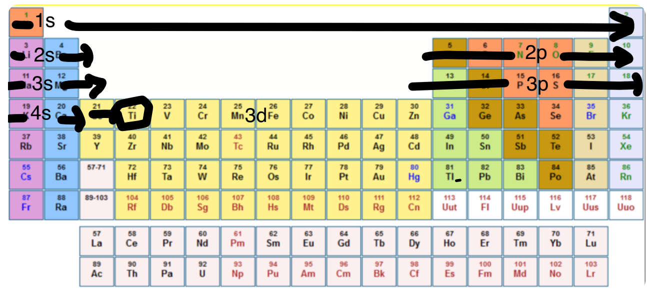
Q10. The ground-state electron configuration of $_{24}$Cr is:

a) [Ar]$4s^2 3d^4$ b) [Ar]$4s^2 4p^6$ c) [Ar]$4s^0 3d^6$ d) [V]$3d^1$ e) [Ar]$4s^1 3d^5$

Short Response.

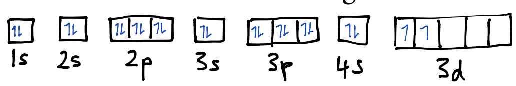
Show all work to receive credit. You must use the factor-label (conversion-factor) method for all conversions. Be sure to show all units and write your answers using the correct number of significant figures or decimal places.

Q11. [10 pts.] a) Write the full electron configuration for $_{22}$Ti.



$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^2$

b) Draw out the full orbital diagram for $_{22}$Ti.



c) Is $_{22}$Ti diamagnetic or paramagnetic? Explain your answer.

Paramagnetic, since it has <u>unpaired</u> e^-'s!

$$\frac{23.4\,g\,N_2}{} \Big| \frac{1\,mol\,N_2}{28.02\,g\,N_2} = 0.8351\,mol\,N_2$$

$-68+273.15=205\,K$

Q12. [10 pts.] Calculate the pressure of 23.4 g of nitrogen gas at a temperature of –68 °C and a volume of 0.310 L using the ideal gas equation, and the van der Waals equation. Note: see the table on the back of the exam for the van der Waals parameters.

van der Waals Constants of Some Common Gases

Gas	a $\left(\frac{atm \cdot L^2}{mol^2}\right)$	b $\left(\frac{L}{mol}\right)$
He	0.034	0.0237
Ne	0.211	0.0171
Ar	1.34	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0266
H_2	0.244	0.0266
N_2	1.39	0.0391

IDEAL : $pV=nRT \Rightarrow p=\frac{nRT}{V}$

$$= \frac{0.8351\,mol \times 0.08206\,\frac{atm\cdot L}{mol\cdot K} \times 205\,K}{0.310\,L} = \boxed{45.32\,atm}$$

vdW: $\left(p+\frac{an^2}{V^2}\right)(V-nb)=nRT$

$$\Rightarrow p+\frac{an^2}{V^2} = \frac{nRT}{V-nb}$$

$$\Rightarrow p=\frac{nRT}{V-nb}-\frac{an^2}{V^2} = \frac{0.8351\,mol \times 0.08206\,\frac{atm\cdot L}{mol\cdot K}\times 205\,K}{0.310\,L - 0.8351\,mol \times 0.0391\,L/mol} - \frac{1.39\,\frac{atm\cdot L^2}{mol^2}\times(0.8351\,mol)^2}{(0.310\,L)^2}$$

$$= 50.65\,atm - 10.09\,atm$$

$$= 40.56\,atm \quad \text{or} \quad \boxed{40.6\,atm}$$

Q13. [10 pts.] Consider the following reaction:

$$2Ca(s) + O_2(g) \longrightarrow 2CaO(s) \qquad \Delta H^\circ_{rxn} = -1271.0\ kJ/mol$$

a) Is this reaction **exothermic** or **endothermic**? $\Delta H^\circ = -ve \Rightarrow$ Releases heat

b) Calculate the amount of heat transferred when 2.4 g of Ca(s) reacts at constant pressure.

$$\frac{2.4\,g\,Ca}{} \Big| \frac{1\,mol\,Ca}{40.08\,g\,Ca} \Big| \frac{-1271.0\,kJ}{2\,mol\,Ca} = -38\,kJ\ (2sf)$$, so 38 kJ of heat is evolved!

c) How many grams of CaO are produced during an enthalpy change (q_p) of –96 kJ?

$$\frac{-96\,kJ}{} \Big| \frac{2\,mol\,CaO}{-1271.0\,kJ} \Big| \frac{56.08\,g\,CaO}{1\,mol\,CaO} = 8.5\,g\,CaO\ (2s.f.)$$

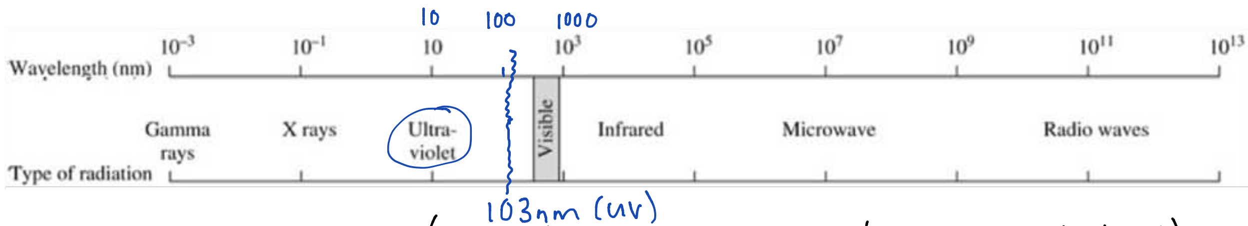
d) How much heat is absorbed when 7.50 g of CaO(s) is **decomposed** into Ca(s) and O_2(g) at constant pressure?

$\Rightarrow$ Reverse rxn, $\Delta H^\circ_{rxn} \times (-1)$

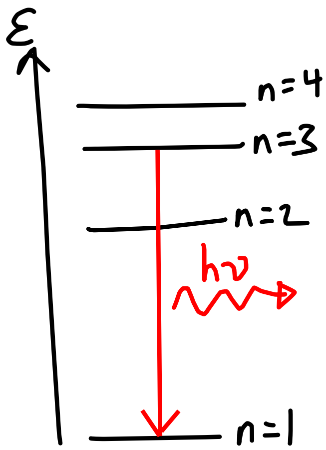
$$2CaO(s) \rightarrow 2Ca(s) + O_2(g) \qquad \Delta H^\circ_{rxn} = +1271.0\ kJ/mol$$

$$\frac{7.50\,g\,CaO}{} \Big| \frac{1\,mol\,CaO}{56.08\,g\,CaO} \Big| \frac{1271.0\,kJ}{2\,mol\,CaO} = 85.0\,kJ$$ absorbed (+)

Q14. [10 pts.] According to Bohr's theory of the atom, calculate the wavelength of light **absorbed/emitted** (**state which**) by the hydrogen atom in an electron transition from $n = 3$ to $n = 1$. What region of the EM spectrum does this wavelength correspond to?



Emission (atom loses energy + emits as a photon!)



$$\Delta E = E_f - E_i$$
$$= E_1 - E_3$$
$$= -\frac{R_H}{1^2} \ominus -\frac{R_H}{3^2}$$
$$= R_H\left(\frac{1}{3^2} - \frac{1}{1^2}\right)$$
$$= 2.18\times10^{-18}\,J \times \left(\frac{1}{9} - 1\right)$$
$$= -1.93\underline{8}\times10^{-18}\,J$$ (Atom loses energy!)

$$E_{photon} = |\Delta E| = 1.93\underline{8}\times10^{-18}\,J$$

$$E = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} = \frac{6.626\times10^{-34}\,J\cdot s \times 3.00\times10^{8}\,m/s}{1.93\underline{8}\times10^{-18}\,J}$$

$$= 1.02\underline{6}\times10^{-7}\,m \left|\frac{nm}{10^{-9}\,m}\right| = 10\underline{2}.6\,nm\,,\ \boxed{UV}$$

Q15. [10 pts.] The specific heat of the organic solvent toluene, C_7H_8, is 1.13 J/g·°C. How much heat is needed to raise the temperature of 0.155 kg of toluene from 22.8°C (room temperature) to its boiling point, 111.0°C?

$q = m \cdot s \cdot \Delta t$

$0.155\,\cancel{kg} \times \frac{1000\,g}{1\,\cancel{kg}} = 155\,g$

$\Delta t = t_F - t_I$

$= 111.0°C - 22.8°C$

$= 88.2°C$

$q = m \cdot s \cdot \Delta t = 155\,\cancel{g} \times 1.13\,\frac{J}{\cancel{g} \cdot \cancel{°C}} \times 88.2\,\cancel{°C}$

$= 15{,}400\,J$ (3s.f.)

Q16. [10 pts.] Calculate $\Delta H°_{rxn}$ for:

$$C(graphite) + 2H_2(g) + ½\,O_2(g) \longrightarrow CH_3OH(l)$$

using the following information

$\times 1 \rightarrow$ $C(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\Delta H° = -393.5$ kJ/mol $\times 1$

$\times 2 \rightarrow$ $H_2(g) + ½\,O_2(g) \longrightarrow H_2O(l)$ $\Delta H° = -285.8$ kJ/mol $\times 2$

reverse $\rightarrow$ $CH_3OH(l) + {}^3/_2\,O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$ $\Delta H° = -726.4$ kJ/mol $\times -1$

$C + \cancel{\tfrac{1}{2}O_2} \rightarrow \cancel{CO_2}$; $\Delta H° = -393.5$ kJ/mol

$2H_2 + \cancel{O_2} \rightarrow \cancel{2H_2O}$; $\Delta H° = -571.6$ kJ/mol

$\cancel{CO_2} + \cancel{2H_2O} \rightarrow CH_3OH + \cancel{\tfrac{3}{2}O_2}$; $\Delta H° = +726.4$ kJ/mol

$+$

$C + 2H_2 + \tfrac{1}{2}O_2 \rightarrow CH_3OH$; $\Delta H° = -238.7\,\frac{kJ}{mol}$

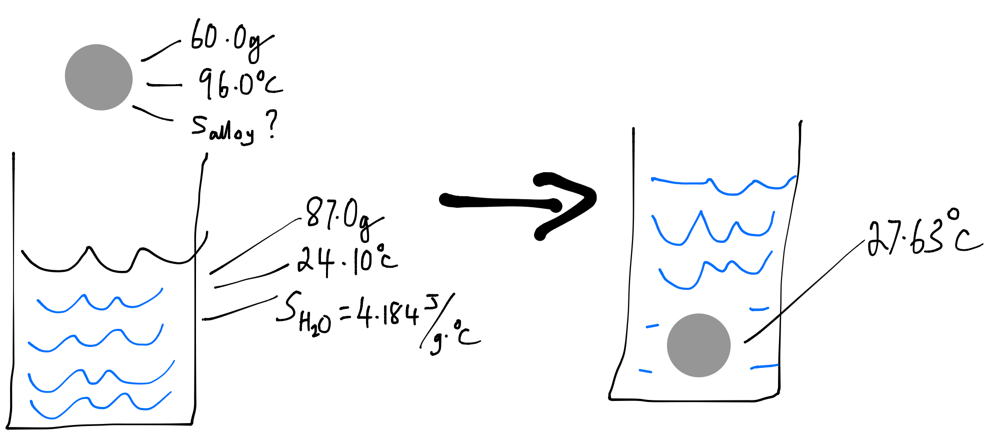
Q17. [10 pts.] Fill in the blanks:

Electrons in atoms are described using four quantum numbers. The principal quantum number, *n*, determines the size/energy of the orbital. The angular momentum quantum number, *l*, which takes values from 0 to n-1, determines the shape of the orbital. The third quantum number, m_l, which is called the magnetic quantum number, determines the orientation of the orbital. The final quantum number, m_s which can only take one of two values, is called the electron spin quantum number.

The symbol for the wavefunction, or orbital, is given by the Greek letter psi, which is written: ψ.

The wavefunction comes from solving the Schrödinger equation—one of the fundamental equations in quantum mechanics.

BONUS: A 60.0 g sample of an alloy was heated to 96.0 °C and then dropped into a beaker containing 87.0 g of water at a temperature of 24.10 °C. The temperature of the water rose to a final value of 27.63 °C. The specific heat of water is 4.184 J/g·°C. What is the specific heat of the alloy?



$\boxed{q_{H_2O} + q_{alloy} = 0}$ 1st Law!

$$\Rightarrow m_{H_2O} \times S_{H_2O} \times \Delta t_{H_2O} + m_{alloy} \times S_{alloy} \times \Delta t_{alloy} = 0$$

$$\Rightarrow S_{alloy} = \frac{-m_{H_2O} \times S_{H_2O} \times \Delta t_{H_2O}}{m_{alloy} \times \Delta t_{alloy}} = \frac{-87.0g \times 4.184\ J/g\cdot°C \times (27.63°C - 24.10°C)}{60.0g \times (27.63°C - 96.0°C)} = 0.313\ J/g\cdot°C$$

Useful Information:

$pV=nRT$ $\left(p+\frac{an^2}{V^2}\right)(V-nb)=nRT$ 1 atm = 760 mmHg = 101325 Pa

$$R = 0.08206\,\frac{\text{atm}\cdot\text{L}}{\text{mol}\cdot\text{K}} \qquad v_{rms} = \sqrt{\frac{3RT}{M}}$$

$q = ms\Delta t$ $q = C\Delta t$ $c = \nu\lambda$ $E = h\nu$ $c = 3.00 \text{ x } 10^8$ m/s

$h = 6.626 \text{ x } 10^{-34}$ J·s

$$E_n = -R_{\text{H}}\left(\frac{1}{n^2}\right) \qquad R_{\text{H}} = 2.18 \text{ x } 10^{-18}\text{ J} \qquad \lambda = \frac{h}{mu}$$

van der Waals Constants of Some Common Gases

Gas	a $\left(\frac{\text{atm}\cdot\text{L}^2}{\text{mol}^2}\right)$	b $\left(\frac{\text{L}}{\text{mol}}\right)$
He	0.034	0.0237
Ne	0.211	0.0171
Ar	1.34	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0266
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
CO_2	3.59	0.0427
CH_4	2.25	0.0428
CCl_4	20.4	0.138
NH_3	4.17	0.0371
H_2O	5.46	0.0305

Periodic Table

1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8	9 VIIIB	10	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1 **H** 1.01																	2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.1	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.88	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.29
55 **Cs** 132.9	56 **Ba** 137.3	57 **La*** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac^** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (264)	108 **Hs** (265)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
^	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)