01/26/2022

# Honors General Chemistry (Chem H2B) Winter 2022
# First Midterm Exam

## Instructions

- Answer the questions below on separate sheets of paper (or blank pages of an electronic document, if you prefer).
- This exam is administered remotely. You may use a calculator, lecture notes and recordings, the textbook, and any static internet content.
- Collaboration with classmates or other humans in any form, posting or distributing the exam, and "getting help" from third parties is *not permitted* and will be treated as a violation of academic integrity.
- Do not round intermediate results.
- Results must be boxed or underlined, rounded exactly to the requested precision, and in the correct units.
- Exam time is 50 minutes, plus a 10 minutes grace period to upload the exam to gradescope. Late submissions will be accepted until 15 minutes past the deadline, but incur a 50% reduction in score. Submission more than 15 minutes late will not be accepted.

**By submitting this exam, you certify under the penalty of an academic integrity violation that all results are your own and were obtained according to the rules above. You consent to be forthcoming to any subsequent questions about your results and how exactly they were obtained, and understand that you may not receive credit if you cannot give a satisfactory answer.**

Use only the following constants and the molar masses provided in the problem:

- Ideal gas constant: $R = 8.3145$ J/(mol K)
- Avogadro's constant $N_A = 6.022 \times 10^{23}$ mol$^{-1}$
- Standard temperature and pressure (STP): $T = 273.15$K, $\quad P = 101.325$kPa
- Molar volume of an ideal gas at STP: 22.414 L/mol
- Fahrenheit ($\theta_F$) to Celsius ($\theta_C$) temperature conversions:

$$\frac{\theta_C}{^\circ C} = \left(\frac{\theta_F}{^\circ F} - 32\right) \times \frac{5}{9}$$

- 1 gal = 3.7854 L

- A periodic table is provided in the appendix.
- Do *not* use the atomic weights from the periodic table, use only the ones provided in a given problem.

## Problems

### 1. Barometric Formula (4 credits)

The barometric formula is given by

$$P_h = P_0 e^{-\frac{Mgh}{RT}}$$

where $P_h$ is the pressure at height $h$, $P_0$ is the pressure at ground level, $M$ is the molar mass of air (28.97 g/mol), $g = 9.8066$ m/$s^2$ is the standard acceleration due to gravity, $R$ is the gas constant, and $T$ is the temperature. This formula has been used to approximate the elevation of mountains. Report to 3 significant figures.

a) A hiker brings a mercury barometer to measure the height of Mount Everest. At the summit, the hiker reports the barometric pressure to be 253.0 Torr at $-9°$C. Use the barometric formula to approximate the height of Mount Everest.

b) Mount Everest has an official height of 8,485 meters. Is the calculated height in a) overestimated or underestimated? Explain potential errors.

c) Given the barometric pressure in a), compute the partial pressure of $O_2$(g) at the summit (P($O_2$)) assuming that the atmosphere is made of 21% $O_2$. With the oxy-hemoglobin dissociation curve given in Figure 1, estimate the percent hemoglobin saturated with $O_2$ assuming that the partial pressure of oxygen in the blood is equivalent to the partial pressure of oxygen at the summit.

### 2. Isothermal Compression (4 credits)

1.87 moles of $Cl_2$(g) at 35°C are compressed isothermally from a volume of 15.0L to 4.79L. Report to 3 significant figures.

a) Sketch the process on the $PV$ diagram. Define all variables and show what corresponds to the work ($W$) done on the gas

b) Compute the work ($W$) and the heat ($Q$) in kJ.

c) What is the final pressure of the gas?

### 3. Decomposition of $N_2O_4$ (2 credits)

Suppose a sample of gaseous $N_2O_4$ has an initial pressure of 6.6 kPa. After some time, a fraction of it has decomposed to form gaseous nitrogen dioxide. The total pressure of the mixture of gases is then 9.8 kPa. Assume the volume and the temperature are kept

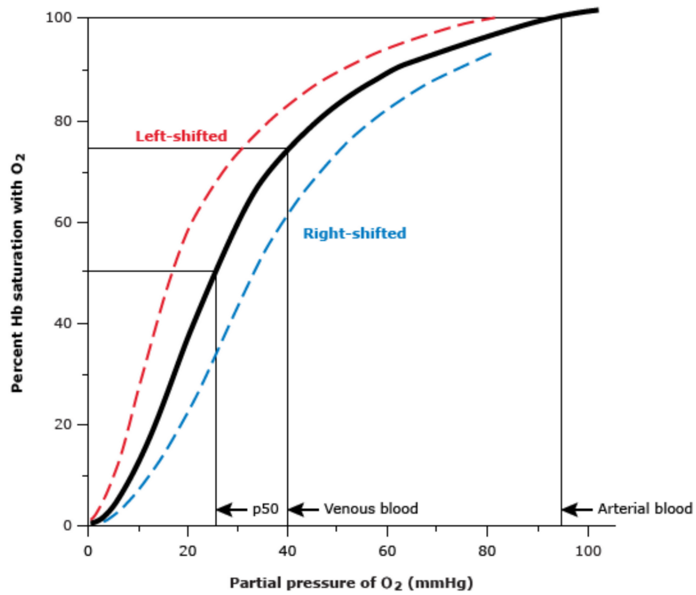


Figure 1: Oxyhemoglobin dissociation curve for human blood.

constant, and the gases are ideal. What percentage of $N_2O_4$ has decomposed? Report your result to 3 significant figures.

**4. Essay Question: World Energy Crisis** (4 credits)

Explain in a few sentences what is meant by the "world energy crisis" and why this colloquial term is imprecise in the context of thermodynamics. How is the "world energy crisis" related to global warming?

**5. Bomb Calorimetry** (5 credits)

Quantitative combustion of 1 g of elemental sulfur, $S_8$(s) ($M$ = 256.48 g/mol), to sulfur dioxde gas increases the temperature of a bomb calorimeter from 296 K to 313.5 K. The heat capacity of the calorimeter is 530 J/K. Report all results to 4 significant figures.

a) Formulate a balanced chemical equation for the reaction including states.

b) Determine the energy of reaction.

c) Your result from b) is a good estimate for the standard energy of reaction. Using this estimate, determine the standard enthalpy of reaction assuming ideal gas behavior.

d) Estimate the standard enthalpy of formation of gaseous sulfur dioxide from these data.

**6. First Law of Thermodynamics** (4 credits)

A bath tub contains 75 gal of water at a temperature of 110 F, which is scalding hot. Estimate the volume of 50 F cold tap water needed to bring the temperature to a more comfortable 104 F. Assume that the bath tub is thermally insulated. Water has a density of approximately 997 kg/m$^3$ and a specific heat capacity of 4.18 J/(g K).

## Appendix

# Periodic Table of the Elements

**Do NOT use the atomic weights given here to answer exam questions!!!**

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| hydrogen 1 **H** 1.0079 | | | | | | | | | | | | | | | | | | helium 2 **He** 4.0026 |
| lithium 3 **Li** 6.941 | beryllium 4 **Be** 9.0122 | | | | | | | | | | | | boron 5 **B** 10.811 | carbon 6 **C** 12.011 | nitrogen 7 **N** 14.007 | oxygen 8 **O** 15.999 | fluorine 9 **F** 18.998 | neon 10 **Ne** 20.180 |
| sodium 11 **Na** 22.990 | magnesium 12 **Mg** 24.305 | | | | | | | | | | | | aluminium 13 **Al** 26.982 | silicon 14 **Si** 28.086 | phosphorus 15 **P** 30.974 | sulfur 16 **S** 32.065 | chlorine 17 **Cl** 35.453 | argon 18 **Ar** 39.948 |
| potassium 19 **K** 39.098 | calcium 20 **Ca** 40.078 | | scandium 21 **Sc** 44.956 | titanium 22 **Ti** 47.867 | vanadium 23 **V** 50.942 | chromium 24 **Cr** 51.996 | manganese 25 **Mn** 54.938 | iron 26 **Fe** 55.845 | cobalt 27 **Co** 58.933 | nickel 28 **Ni** 58.693 | copper 29 **Cu** 63.546 | zinc 30 **Zn** 65.39 | gallium 31 **Ga** 69.723 | germanium 32 **Ge** 72.61 | arsenic 33 **As** 74.922 | selenium 34 **Se** 78.96 | bromine 35 **Br** 79.904 | krypton 36 **Kr** 83.80 |
| rubidium 37 **Rb** 85.468 | strontium 38 **Sr** 87.62 | | yttrium 39 **Y** 88.906 | zirconium 40 **Zr** 91.224 | niobium 41 **Nb** 92.906 | molybdenum 42 **Mo** 95.94 | technetium 43 **Tc** [98] | ruthenium 44 **Ru** 101.07 | rhodium 45 **Rh** 102.91 | palladium 46 **Pd** 106.42 | silver 47 **Ag** 107.87 | cadmium 48 **Cd** 112.41 | indium 49 **In** 114.82 | tin 50 **Sn** 118.71 | antimony 51 **Sb** 121.76 | tellurium 52 **Te** 127.60 | iodine 53 **I** 126.90 | xenon 54 **Xe** 131.29 |
| caesium 55 **Cs** 132.91 | barium 56 **Ba** 137.33 | 57-70 * | lutetium 71 **Lu** 174.97 | hafnium 72 **Hf** 178.49 | tantalum 73 **Ta** 180.95 | tungsten 74 **W** 183.84 | rhenium 75 **Re** 186.21 | osmium 76 **Os** 190.23 | iridium 77 **Ir** 192.22 | platinum 78 **Pt** 195.08 | gold 79 **Au** 196.97 | mercury 80 **Hg** 200.59 | thallium 81 **Tl** 204.38 | lead 82 **Pb** 207.2 | bismuth 83 **Bi** 208.98 | polonium 84 **Po** [209] | astatine 85 **At** [210] | radon 86 **Rn** [222] |
| francium 87 **Fr** [223] | radium 88 **Ra** [226] | 89-102 ** | lawrencium 103 **Lr** [262] | rutherfordium 104 **Rf** [261] | dubnium 105 **Db** [262] | seaborgium 106 **Sg** [266] | bohrium 107 **Bh** [264] | hassium 108 **Hs** [269] | meitnerium 109 **Mt** [268] | ununnilium 110 **Uun** [271] | unununium 111 **Uuu** [272] | ununbium 112 **Uub** [277] | | ununquadium 114 **Uuq** [289] | | | | |

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| *Lanthanide series | lanthanum 57 **La** 138.91 | cerium 58 **Ce** 140.12 | praseodymium 59 **Pr** 140.91 | neodymium 60 **Nd** 144.24 | promethium 61 **Pm** [145] | samarium 62 **Sm** 150.36 | europium 63 **Eu** 151.96 | gadolinium 64 **Gd** 157.25 | terbium 65 **Tb** 158.93 | dysprosium 66 **Dy** 162.50 | holmium 67 **Ho** 164.93 | erbium 68 **Er** 167.26 | thulium 69 **Tm** 168.93 | ytterbium 70 **Yb** 173.04 |
| **Actinide series | actinium 89 **Ac** [227] | thorium 90 **Th** 232.04 | protactinium 91 **Pa** 231.04 | uranium 92 **U** 238.03 | neptunium 93 **Np** [237] | plutonium 94 **Pu** [244] | americium 95 **Am** [243] | curium 96 **Cm** [247] | berkelium 97 **Bk** [247] | californium 98 **Cf** [251] | einsteinium 99 **Es** [252] | fermium 100 **Fm** [257] | mendelevium 101 **Md** [258] | nobelium 102 **No** [259] |