No Analytical crib available
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1. (a) The net reaction of glycolysis between these two intermediates is: Glucose + 2ATP → Fructose 1,6-bisphosphate + 2ADP + 2H₂O. It is catalyzed by hexokinase, phosphoglucoisomerase, and phosphofructokinase. The net reaction of gluconeogenesis between these two intermediates is: (b) Fructose 1,6 bisphosphate + 2H₂O → glucose + 2P₁. It is catalyzed by Fructose 1,6 bisphosphatase, phosphoglucoisomerase, and glucose-6-phosphatase. (b) Two thermodynamically favored phosphate transfers from ATP to glucose drive glycolysis forward. The reaction cannot run backwards because the energy contained in the phosphate ester bonds in G-6-P and F-1,6-P₂ is insufficient to drive the formation of ATP from ADP. (c) Phosphofructokinase is inhibited by ATP, since ATP raises the Kₘ of the Phosphofructokinase for its substrate. Fructose 1,6 bisphosphatase is inhibited by AMP, the energy depleted form of ATP. (d) Insulin acts to promote the storage of energy when food is abundant. Glucagon secretion is stimulated by low blood glucose levels, and its general effect is to oppose the action of insulin. Insulin upregulates the transcription of glucokinease, phosphofructokinase, and pyruvate kinase, while glucagon downregulates their transcription. Insulin also induces the translocation of glucose transporters from the ER to the plasma membrane, thereby facilitating entry of glucose from the blood into muscle and liver cells. Epinephrine also regulates these pathways by activating cAMP dependent protein kinase (PKA), which in turn promotes glycogen breakdown and inhibits glycogen formation. This leads to increased availability of glucose. Moreover, when epinephrine or glucagon elevates cAMP, a second phosphofructokinase (PFK2) is phosphorylated by protein kinase A. This leads to synthesis of Fructose 2,6-bisphosphate, a very potent activator of phosphofructokinase (PFK-1) and glycolysis.

2. (a) 11.0 kcal/mol
(b) 46 kg; 68%

3. (a) One function of the pentose phosphate pathway is to produce five carbon sugars (ribose) for synthesis of RNA and DNA. A second function is to produce NADPH, a reducing agent required in many biosynthetic reactions. (b) Patients deficient in glucose-6-phosphate dehydrogenase experience a hemolytic anemia when they eat foods containing oxidants such as fava
beans, because such oxidants (divicine in the case of fava beans) oxidize normal hemoglobin (ferrous Hb) to methemoglobin (ferric Hb). This methemoglobin is commonly reduced back to ferrous hemoglobin by methemoglobin reductase plus NADPH. However, in patients with a glucose-6-phosphate dehydrogenase deficiency, the pentose phosphate pathway does not produce enough NADPH and oxidized hemoglobin cannot be reduced back to normal Hb. The resulting accumulation of oxidized hemoglobin leads to red cell instability and a hemolytic anemia.

(c) Cancer cells commonly increase the amount of glucose entering the pentose phosphate pathway relative to the amount entering glycolysis in order to generate the ribose sugars necessary for the rapid synthesis of DNA required for frequent cell division.
(1) 

(A) 

(B) 

(C) 

(D) 

(E) 

(F) 

(2) Binds DNA causing crosslinking of DNA, which ultimately triggers apoptosis.
(3). \[ \text{Pt}^{2+} + I^{-} \rightarrow \text{Pt}^{2+} + I^{+} \]
\[
\text{AgOTf} + \text{H}_2 \rightarrow \text{Pt}^{2+} + \text{N}_2
\]

\[
\text{Oxaliplatin}
\]

(4). \[ \delta \quad \text{H} \quad \text{OH} \]
\[
\delta \quad 7.9 \quad \text{P-H} \quad J_{\text{PH}} = 780 \text{ Hz}, \quad J_{\text{HF}} = 115 \text{ Hz}
\]
(doublet of doublets)

\[ ^{31} \text{P} \quad \text{would be doublet of doublets without proton decoupling} \]
\[ \delta \quad J_{\text{PH}} = 780 \text{ Hz} \quad J_{\text{HF}} = 1030 \text{ Hz} \quad (\text{you would not know this coupling const.}) \]

\[ ^{19} \text{F} \quad \text{would show doublet of doublets} \quad J_{\text{PP}} = 1030 \text{ Hz} \quad J_{\text{FH}} = 115 \text{ Hz} \]
1. (50 pts) Living polymerization reactions have been developed over the last 30 years to provide precise control over the uniformity, predefined molecular weight, controlled topology, and precisely placed functional groups within a highly diverse family of polymeric architectures (e.g., stars, bottlebrushes, combs, etc). This family of reactions is a key tool in the development of nanomaterials with well-defined structures and properties. Write plausible mechanisms for any two of the following three living polymerization reactions.

K. Matjeszewski & NV Tsarevsky, "Macromolecular Engineering by Atom Transfer Radical Polymerization" JACS Perspective 2014 136, 6513-6533
NJ Warren & SP Armes, “Polymerization-induced Self-Assembly of Block Copolymer Nano-objects via RAFT Aqueous Dispersion Polymerization” JACS Perspective 2014 136, 10174-10185

2. (25 pts) Höger, Sheiko & Matyjaszewski [JACS 2014 136, 12762-12770] recently reported the synthesis of molecular stars with spoked wheel cores and bottlebrush arms using an ATRP approach. Their GPC data indicated the formation of molecular stars with the predicted molecular weight (i.e., where $R^2$ in the figure below is a bottlebrush arm comprised of (300-$g$-150)$_6$ units); however, their AFM data on mica substrates suggests that the structure and uniformity of the sample is time-dependent. **Briefly rationalize their findings.**

The AFM data at $t = 0$ suggests that molecular star polymers are produced via ATRP polymerization of methacrylate-modified bottlebrush arms. Extended exposure of the sterically congested high molecular weight arms on the planar surface used for AFM analysis; however, leads to mechanical covalent bond breakage & fragmentation of the arms from the central wheel in a time-dependent manner.

3. (25 pts) Armes and coworkers have recently reported the synthesis of nanoparticles with relatively controlled diameters using 4,4'-azobis-4-cyanopentanoic acid (ACVA) as initiator, benzyl methacrylate as monomer, and two different macromolecular chain transfer reagents to generate diblock copolymers in a RAFT polymerization sequence in ethanol. The authors systematically varied the polymethacrylic acid chain transfer agent ratios while keeping the benzyl methacrylate feed constant. The resulting diblock copolymer product solutions where then deposited onto glow-discharged electron microscopy grids, stained with 0.75% UO₃(Ο₂CH)₂, and analyzed by transmission electron microscopy to produce the data set below. **Draw the products of the RAFT polymerization and briefly rationalize their observations.**

![Diblock copolymers diagram](image)

R = ![R diagram]

Z = ![Z diagram]

**2 diblock copolymers:**
PMMA₆₂-PBzMA₃₅₀
PMMA₁₇₁-PBzMA₃₅₀

![TEM images and phase diagram](image)

**Figure 1.** Representative TEM images and corresponding phase diagram determined for \([xPMMA_{62} + (1-x)PMMA_{171}]\)-PBzMA₃₅₀ particles synthesized by RAFT dispersion polymerization of BzMA at 70 °C using a binary mixture of PMMA₆₂ and PMMA₁₇₁ macro-CTAs in ethanol at 20% w/w solids. Intensity-average diameters and polydispersities were determined by DLS in ethanol (0.10% w/w solids). S indicates spheres and V indicates vesicles.
The graph shows a phase diagram of mixing two diblock copolymers that share a solvophobic block (i.e., PBzMA\textsubscript{350}) of identical block size, but solvophilic blocks of differing molecular weight. At low molar ratios of the PMMA\textsubscript{62}-PBzMA\textsubscript{350} diblock copolymer, the higher PMMA\textsubscript{171}-PBzMA\textsubscript{350} diblock composition drives spherical polymer micelle formation due to the larger occupied volume of the PMMA\textsubscript{171} block relative to the PBzMA\textsubscript{350} block. As the two diblock copolymers are mixed at (or above) equivalent ratios, the structure transforms to a vesicle-like structure where the outer vesicle surface is comprised of predominantly PMMA\textsubscript{171} blocks and the inner surface is composed of predominantly PMMA\textsubscript{62} blocks, with the lamellae composed of the PBzMA\textsubscript{350} material.


**Low weight ratio of PMMA\textsubscript{62}-PBzMA\textsubscript{350}**

**Weight ratio of PMMA\textsubscript{62}-PBzMA\textsubscript{350} \geq 0.45**